About This Book

...usiastically received as the most satisfac... guide to the study of the stars for ama..., NEW HANDBOOK OF THE HEAVENS is a ...ctical, fascinating book for students and lay... alike. Offering star charts and data, de...scriptions of the heavenly bodies, astronomical facts and lore, this book gives beginners as well as those more advanced ... rewarding key to the ...standing and enjoyment of astronomy.

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—ARTHUR DRAPER, *Director Buhl Planetarium*

NEW HANDBOOK OF THE HEAVENS

(With Minor Abridgments)

by

Hubert J. Bernhard

Dorothy A. Bennett, A.B.

Hugh S. Rice, A.M., Ph.D.



A MENTOR BOOK

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Preface

e have enjoyed knowing the stars. We are among the thousands who have found them old friends, to which we can turn time after time for refreshing thoughts and relief from the stresses and troubles of every-day life.

We have written this book so that others might share this relationship with us. It has been prepared as simply as possible, and it tells of things that anyone can see and understand for himself merely by looking up at the heavens.

But we have found that a great many people, having once looked up, want to lend wings to their explorations by using field-glasses or telescopes. To most such "home astronomers" their instruments have a limited use, and so we have included a few telescope suggestions that may be of help to our readers as they grow more ambitious, and to advanced students as well. We have also included carefully prepared lists of the best celestial objects available for observation.

We hope that our efforts, meant both to be read at leisure and to aid actual observations in the field, may reveal to you not merely a new world—but an unsuspected universe!

Hubert J. Bernhard
Dorothy A. Bennett
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1 Introduction to the Heavens

IT IS FUN to know the stars. When night gathers overhead thousands of them appear. There are bright stars and faint ones, near ones and far. Some seem scattered at random over the sky while others seem mingled in patterns.

And there are exciting events that are always occurring among them. Once in a while a new star appears, and if you know the old ones you can always pick the new one out. There are the changing phases of the moon and the moon's shifting place along the zodiac. Then there is the possibility that one of those wandering objects, the comets, may appear. If you know the stars, you can easily pick out the visitors from space. And one night, as you are watching the sky, brilliant shooting stars will flash through the heavens. You can add a really important bit of information to astronomy if you know how to watch them and keep records of them.

With even a box camera you can make a permanent record of some celestial events. The rotating earth will shift your camera beneath the stars, and across the photographic plate those distant suns will trail bright arcs. The moon as it drops behind the trees will leave a gradually dimming trail as its light passes through more and more atmosphere and is therefore absorbed.

When you have made your first step into observing the sky you can always go farther. Build a telescope and you can explore the depths of the universe. Double stars and clusters, variable stars and nebulae—all lie within your reach.

Most intriguing of all is the fact that the sky is so full of fascinating things that there is more than a lifetime's entertainment there. In one night one can find many of the sta groups, perhaps observe several of the planets, identify dozens of features or more on the moon, and with the telescope spot numerous double stars, clusters, and nebulae. The next night the same sky will hang overhead but there are thousands of double stars, hundreds of variable stars, innumerable markings on the moon, and limitless wealth of still undiscover d wonders within reach of the telescope. The next season a whole new realm of the heavens will be there to explore.

is, of course, everywhere 90° from both poles just as it is on earth. The earth and sky can be considered two great globes, one within the other. It is 360° around any circle such as the earth's equator for instance. The half-circle from the north pole to the south pole is 180° and the quarter-circle from the equator to the pole is 90°. If the pole star is half-way up the sky in the north, then the equator is about half-way up in the south. Of course, to most people this doesn't make any difference, but to sailors and surveyors it is important. They use such marks of reference in the heavens as a means of establishing points of reference on the earth.

So excellent an index of one's latitude is the altitude of the pole star that it has guided sailors since earliest time. Even today this and other stars are used by modern aviators in crossing the trackless ocean.

No one has ever walked around the earth with a measuring tape, yet we know that it is about 25,000 miles in circumference. This is possible to compute approximately when you know the distance between two points on the earth on the same meridian of longitude and then can measure the height of the pole star in each place. Thousands of years ago Eratosthenes in Egypt first determined the size of the earth by a similar method. He believed the world to be round and knew consequently that its circumference measured 360° as does any circle. Hearing from a traveler that the sun appeared at a different height when viewed at the same time from two different cities, he measured the difference in height in degrees. Having this figure, and comparing it with 360° he knew what part of the earth's total circumference was represented by the distance between the two cities. When he measured that distance he was able by simple multiplication, to estimate correctly that the earth is about 25,000 miles around.

In the same way no one has ever walked through the earth from pole to pole, yet we know that it is about 7900 miles in diameter. It is possible to figure this out again because we know the earth is round like a baseball. We can measure a baseball and then discover how much farther it is around it than through it. If it is 3 inches in diameter it will be roughly 9.4 inches around. There is a definite mathematical relationship between circumference and diameter in any circle, and we can apply the same rule to the earth.

By other mathematical means, it is possible to measure the 93,000,000 miles distance of the earth from the sun. Our world is one of nine planets that move around the sun. The sun is always shining, so one side of each planet is always lighted. And as the planet rotates upon its axis, an observer on that turning globe sees the sun apparently rise and set.

There is a real satisfaction in knowing which stars to eye in summer what different stars will decorate winter sk which planets shine in the morning sky what others rest in the west after the setting of the sun

Long ago people traced pictures among the stars. The carved these heavenly figures on stones in Babylonia, drew them on papyrus in Egypt fixed them on marble in Greece and painted them on buffalo skins in the American west. The ancient constellation figures can still be recognized, for the stars seem to stay the same in relation to their neighbors in a lifetime and even a thousand years. Really they are a drifting in space, but they are so far away that their motio cannot be noticed in a lifetime. To the unaided eye the seem fixed and permanent in position.

Even though they do seem fixed in relation to one another all the stars appear to move together around the earth. Long ago people thought they actually did circle the earth 24 hours the way the sun seems to do But then it was dis covered that the earth itself was turning on its axis and tha the apparent motions of the sun and stars were the result o this movement of the earth.

There is one star though that does not seem to chang much It is the brightest in the Little Dipper Its proper name is Alpha (α) its family name, Ursa Minor hence the sta is called Alpha Ursae Minoris and is nicknamed pole star Hanging over the north pole of the earth, over one end of the axis on which the earth turns, it is the brightest star clos to the north celestial pole All the stars seem to rotate around the north star which itself makes a small circle around the celestial pole every 24 hours because it is really 1° away from the true pole To the casual observer it appears to be quite motionless and always to occupy the same place for any one latitude in the northern hemisphere (where pole star means the north star)

However Polaris, the north star has a different position for every latitude within that hemisphere In the New England states it is about half way up the northern sky wherea t the north pole it is overhead. At the equator however the pole star is just at the horizon So if you travel to the north the pole star climbs higher the farther you go When you sail south the star drops lower and disappears if you cr ss the equator into the southern hemisphere. There the south polar region of the sky comes into view and in the same fashion these stars climb higher above the southern horizon one travels from the equator toward the south pole

Just as there is a pole of the sky over the earth s pole there is a celestial equator that hangs over the terrestrial on

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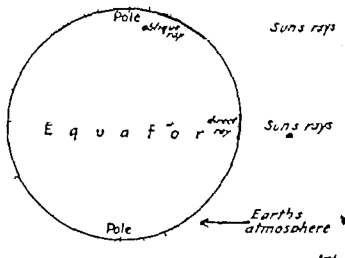


FIGURE 1 INSOLATIO.

Insolation depends upon the inclination f the sun s rays, and a the absorption of the atmosphere when we consider equal areas, a c stant output of solar energy and equal distances from the sun C diagram shows these two effects, closely connected with the hange seasons. In high latitudes, bundle f solar rays is spread o er a la area and thus is less concentrated than similar bundle of ray lower latitudes. Similarly it is evident that oblique ra s pass throu a greater thickness of atmosphere consequentl losing much of the lighting and heating po er

In considering the motions of the earth it is convenient assume that the sun's position is a con tant one Since t earth does not move in a perfect circle around the sun a sometimes nearer and sometimes farther from it In Janua we are about 3 000 000 miles closer to the sun than in Ju The varying distance does not make winter and summ however The actual shift of the season comes from sev different causes. The earth is round, wrapped bout with blanket of air and tipped upon its axis Sunlight must pe trate the air before it can warm the earth ben ath. Vertic rays of sunlight which strike directly down up n the pla are the most effective as the accompanying di gram sho because they pass through a minimum amount of r and f upon a comparatively small surface area thus oncentrati their heat. The slanting rays, on the other hand, pass throu a much greater thickness of

land, and in doing so lose much of their heat in the air. Then hitting the surface on a slant, the rays are spread over a greater area than the vertical ones.

Now if the axis of the earth were straight up and down (perpendicular) to the plane in which the earth moves, vertical rays would always strike at the equator and slanting rays would strike at higher latitudes. But the earth is tipped. Its axis is inclined 23½° away from the perpendicular to the plane in which it moves about the sun. As the world moves around the sun with its axis always tipped at the same angle and pointing in the same direction, first one pole and then the other is nearer the sun. The direct rays shift from 23½° north of the equator to the same distance south of that imaginary line. The sun shines alternately 23½° beyond the north and then beyond the south pole. The days grow long in the northern hemisphere and then become short. These are the underlying causes for the change of the seasons.

As the seasons come and go one can see the changes in the sun's position that bring the seasons about. During some months, the sun is higher in the heavens at noon than during others. And, too, it seems to shift its place constantly against the background of stars as the earth moves around it. The sun's light is so scattered through the air that the sky is too bright for us to see the stars, but they are always there. On the occasion of a solar eclipse makes it dark enough in the daytime for us to see them. We discover that the stars close to the sun in summer are the very ones that we see in the night skies of winter. Of course, if the eclipse occurs in winter we see stars near the sun that we saw on the nights of summer.

There is a particular section of the sky that the sun and planets always occupy. The ancients recognized it and divided it into constellations, all but one of which represented some animal. It was called the zodiac, or band of animals, and along its path the sun seems to move.

As the earth revolves around the sun it makes the sun have an apparent motion among the stars—really a reflection of the earth's true movement. Although we cannot observe it quite as easily as the daily rising and setting of the sun, we can detect it as the ancients did. They noticed that each evening after the sun went down certain stars of the zodiac could be recognized above the sunset point. As the nights passed, the same stars set earlier and seemed to go to meet the sun. The stars that were above the western horizon at sunset at the beginning of the month would set with the sun at the end of the month. Thus the sun seemed to progress from west to east along the center of the zodiac.

[illegible] heavenly path around the earth, the moon

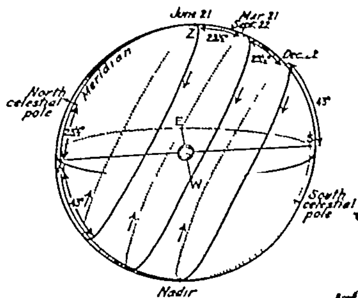


Figure 2 THE SEASONS

At different seasons f the year the noon sun appears at different a tudes to an observer at any one station. Our diagram is drawn for ɡ locality in latitude 23½ N Most important cause of the change seasons, as illustrated in this diagram is the difference in length(day and night at different times of the year for the length of the su path bove the horizon indicates the daylight hours.

moves regularly among these same stars, as do the planets various intervals. The moon s path, always close to the sun crosses it in two places. Where the orbits cross, eclipl occasionally occur Either the moon comes between us a the sun and hides the latter or the moon enters the earl shadow and is darkened. Because of the eclipses that occ here the sun's path was named the ecliptic.

But the earth is tipped upon its axis, and as a result of d the celestial equator is inclined to the ecliptic and crosses Where equator and ecliptic cross are the equinoxes—poi along the sun s apparent path reached near March 21 a September 23 each year From these points in the appare path the sun s rays strike the equator directly and all ov the earth there is equal day and night.

After the equinox times, the situation changes. Climbi

h of the equator after March 21 the sun's vertical rays h latitudes north of the equator On June 21 or 22, the is at its most northern point. Then it takes the northern of the earth longer to turn through sunlight than through night. The northern nights are short, days are long. This be time of the solstice—summer for the north but winter the south. Each day after late June the sun goes south. It ches the equator September 23 Fall begins, and day and ht are equal again as the sun's most direct rays fall at the ator After this the sun continues to go farther south and December 21 or 22 it has dropped to the Tropic of Capri-n. The warm rays and the long days have gone south with sun. The short and cold days of winter are in the northern misphere and the sun is very low in the northern sky

As the sun changes its noon-time or meridian position, it o changes its place of rising and setting. At equinox time sun rises exactly east and sets exactly west. On those days sun is on the celestial equator As the earth rotates on its s, the sun rises in the east and seems to move across the on the equator setting in the west. As the sun climbs th of the celestial equator it rises to the north of the east nt, and sets to the north of the west point, reaching its thest position in each case about June 21 Then as it begins move back to the equator it again rises due east in September but by December when it is far south of the celestial uator it rises to the south of the east point and similarly s to the south of west.

Long ago the ancient peoples learned to tell the exact time the seasons by watching the shift of the sun place of ing and setting. Early monuments in China, Japan, Central erica, and the American southwest were oriented to make ervations of these changes possible. E en the Stonehenge England was used for this purpose.

And of course as the earth turns on its axis each day the n rises at different times for different longitudes. This makes change in time that was not even thought of in the olden ys before people could keep track of what was happening the other side of the world. But now that radio connects e whole of our planet instantaneously it is possible to be te sure exactly what time it is in China as well as in New rk. In fact it is possible actually to tell your longitude from e time—because the two are closely related. When the sun ts in London it is still dark in New York on the other hand, is already afternoon in Shanghai. People on the east coast the United States must wait 3 hours for the sun to appear ove their eastern horizon after it has come up in England. nd in the same fashion, people in San Francisco must wait 3

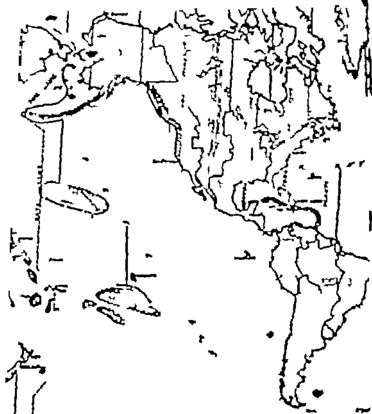


Figure 3 Time-Zones

The earth is divided into 24 standard time zones, each 15° wide in longitude. This section of a U. S. Coast and Geodetic Survey diagram shows only the western hemisphere. The time in all stations of one zone normally differs by a full hour from that in adjoining zones and zones vary in outline according to the convenience of localities within. Diagonally shaded regions indicate the few areas where standard time does not differ by one whole hour from adjoining zones.

hours to see the sun after it has come up in New York. Once this was merely interesting, but now it is used to help locate the positions of ships at sea and the big clipper airplanes that fly the ocean.

All that is necessary to determine difference in longitude is to know the time of any two places on the earth and from this you can tell the east-west distance between them. The usual method is to use Greenwich time as a standard from

...th to measure, and then figure local time from the altitude ...the sun or other astronomical data and the tables in an ...meris or nautical almanac. The time difference is directly ...vertible into longitude distance between the observer and ...Greenwich meridian. You can use stars instead of the ..., and they are really preferable. So modern ships and air... ...nes all carry a clock that shows Greenwich civil time, and ...lios with which to check the clocks. This is now called by ...tronomers Universal time, because it is used the world over ...the establishment of longitude and for many other scientific ...rposes. Stations located 15° of longitude to the west of the ...eenwich meridian have local time reading one hour earlier ...n Greenwich time; stations 75° to the west, or in the East... Standard time-zone, have their local clocks 5 hours earlier ...n Greenwich time. So it is around the world. One can tell ... time by the sun wherever he is on the earth. Comparing ...t with the Universal time he can establish his position east ...d west of the prime meridian. One of the most important ...ings that time does then is to help fix positions on the ...rth, and so it is possible to tell latitude from the pole star ... the sun, and longitude from the sun or the stars.

Star-gazing is like a magic carpet that can carry you away ...lions of miles from home and remove you far from the ...airs of every day. You need only to put your head out the ...ndow to start upon this trip of exploration into the outer ...st reaches of space, where one can sense the immenseness ...the universe and the remarkable law and order that prevail ...re.



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...horizon. After reaching the south pole we would find that ...y star south of the celestial equator had become circumpolar. For each latitude there is a different group of circumpolar stars.

You can easily discover what stars are circumpolar for your ...ality by measuring the altitude of the pole star or looking ...your latitude in the atlas. Any star that is no farther from ...e pole star than the pole star is from the horizon will be ...cumpolar. Like this circumpolar area which is always visible, there is from the same latitude an equal section in the ...her hemisphere always invisible. As you go from equator to ...le the circumpolar area increases. As you go from pole to ...uator it decreases.

Since the greater part of the population of the United ...ates and of many parts of Europe lies in the middle latitudes, most people are familiar with the stars that are circumpolar for the middle latitudes of the northern hemisphere. Among these the Big Dipper (or Great Bear) the Little Dipper, Cassiopeia, Perseus, and others are well known.

The Big Dipper properly known as Ursa Major is composed of seven bright stars. Four stars form the bowl, three the handle of the Dipper. The same three stars that we see in the handle were employed by the Greeks and Romans to make the tail of the Great Bear. The four we use to make a bowl they used in picturing the bear's hind quarters. Despite the different pictures that have been made with these seven stars, their arrangement has always been much the same. The Egyptians described them as a hippopotamus; yet they saw the same arrangement that we find today.

Five of the Dipper's stars seem to be of the same brightness, and two are fainter. All the stars that we can see with the eyes alone have been classified according to their brightness and placed in six arbitrary groups. The 20 at the top of the list are 2½ times brighter than the greater number of stars in the second-magnitude group. The next type, the third-magnitude stars, are 2½ times less bright than those of the second-magnitude group. This proportion is used throughout the scale.

Some 5000 stars can be seen with the unaided eye all over the earth throughout the year but only some 2500 to 3000 at any one time in any one place. They range from the sixth magnitude to the first, and the first-magnitude stars are 100 times as bright as the faintest stars that we can see.

There are a few stars brighter than first magnitude. These

The stars visible in these middle northern latitudes are shown as they appear ... [illegible] ... clearly constructed revolving device, the "Star Explorer." This ... may be obtained [illegible] from the Junior Astronomy Club, ... [illegible]

2 Stars around the Poles

WHEREVER ONE lives upon the earth there are certain st that he can see night after night At the north pole of t earth, for instance, one always sees the same stars—th never set and are visible at all hours every night As the ea turns on its axis each 24 hours the whole sky seems to circ with every star at a definite and constant height above t horizon Those near the horizon seem to move parallel to and those overhead circle in a direction opposite to the han of a clock Every star seen from the pole is circumpolar b these are in only half the sky the other half never rises at t north pole and is forever invisible from that point

Suppose, though, that you were to leave the north pole a go as far south as Minneapolis. This city and all others the same latitude are exactly half way between the equat and the poles. The pole star therefore hangs half way do the sky instead of at the zenith where it was seen from t north geographical pole In Minneapolis all the stars in vi on any night still seem to move around the pole star but s *of them rising out of the east and climbing above the southe* horizon will sink from view in the west and be out of si for some time during the night Above the northern horiz there are certain stars that continually swing around the no celestial pole and never disappear Since they are in view f every hour of every night they are among the easiest to fi and identify They are the keyst nes of con tellation stud the circumpolar stars They form an easy gu de to ot near by groups.

If our journey be extended and we continue t the equa we find the pole star at the horizon and no st r umpol for all of them both rise and set. Our pole star P l ris, lies the northern horizon and off at the southern h rizon t south celestial pole is located Continuing our journey to t south we would find the south polar region ri g highe When we reached Tasmania the south celestial p l would nearly half way up the sky Again a group of wou circle the pole remaining in view through the whole of t night. But at this pole they move in the oppos i directio

owl. The two in the bowl which correspond to the point of the Great Dipper are considerably brighter than their lbors. Just as the pointers are called by that name, so the esponding stars in the Little Dipper are called the rdians. They seem always to swing about the pole star. mbus mentioned these stars in the log of his famous ney across the ocean and many other navigators have d them useful in measuring the hour of the night and r place upon the sea.

he Dippers are so arranged that when one is upright the r is upside down, and their handles extend in opposite ctions. Winding in between the two Dippers is part of on, the Dragon. The end of his tail lies almost directly veen the pointers and the pole, and the coils of his long y curve out beyond the Little Dipper's bowl, swing back ard Polaris again, and finally turn toward the constella- of Hercules in a reverse S.

After you have recognized the Great Dipper traced the ters to the pole star and found the Little Dipper hanging n Polaris—you might trace a line from the pointers to the r and extend it an equal distance on the other side. There ll lead you close to a W-shaped group, Cassiopeia. Across pole from Ursa Major and equally distant from Polaris this group that represents, some say a big chair upon ch the ancient queen of Ethiopia is seated.

n the course of a night Ursa Major and Cassiopeia circle heavens like the opposite sides of a wheel. At 9 p.m. May he Great Dipper hangs upside down, Cassiopeia resembles W right side up on the opposite side of the pole. As the h turns, Cassiopeia climbs the northeastern sky while Great Dipper drops down to the northwestern horizon. At the in middle latitudes, their positions are reversed by a rter turn. At 9 a.m. they have exactly changed places. But next evening the Great Dipper is again high overhead, and siopeia hangs just above the horizon.

Cassiopeia is typical constellation. It is group of stars t to us looks always the same. In fact, it appeared the ne more than thousand years go when it first received name and even longer ago than that when people first erved it. Yet some of the stars in this constellation are rer to us than others, and all of them are separated from another by millions of miles. From some other corner of universe these same stars would not form the same picture. this same corner of the universe at some other time their angement will be different. For all the stars are really ing through space. The speeds and directions of hundreds known. They are so distant from the earth that it takes

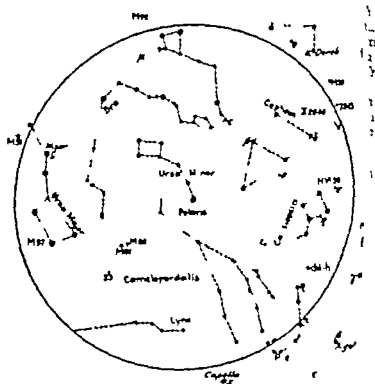


Figure 4 North Circumpolar Constellations

are reckoned on the same scale Stars 2½ times as brigh first magnitude are designated as zero magnitude St brighter than that are labeled *minus* Thus Sirius our brig est star is magnitude —1 58 The lowest value represents greatest brilliance So Polaris is among the second-magnit group and five of the seven stars in the Great Bear are this same brilliance It is no wonder then that the Dipper is easy to find t a glance and Pol ri ea y to loc when one follows the pointers of the Dipper

The "pointers" are the two stars opposite the handle of Great Dipper By following a line drawn from the bott of the bowl through the pointers and extended about times the distance between them one comes to the pole s To make sure that this is Polaris one should learn U Minor the Little Dipper as well. The Little Dipper Polaris in the end of its handle the brightest st r in the c stellation. There are three tars in the handle and four

bowl. The two in the bowl which correspond to the point the Great Dipper are considerably brighter than their [illegible]bors. Just as the pointers are called by that name, so the [c]orresponding stars in the Little Dipper are called the [gu]ardians. They seem always to swing about the pole star [Co]lumbus mentioned these stars in the log of his famous [jou]rney across the ocean and many other navigators have [fou]nd them useful in measuring the hour of the night and [the]ir place upon the sea.

The Dippers are so arranged that when one is upright the [oth]er is upside down, and their handles extend in opposite [dir]ections. Winding in between the two Dippers is part of [Dr]aco, the Dragon. The end of his tail lies almost directly [bet]ween the pointers and the pole, and the coils of his long [bod]y curve out beyond the Little Dipper's bowl, swing back [tow]ard Polaris again, and finally turn toward the constella[tion] of Hercules in a reverse "s

After you have recognized the Great Dipper traced the [poin]ters to the pole star and found the Little Dipper hanging [fro]m Polaris—you might trace a line from the pointers to the [pole] and extend it an equal distance, on the other side. There [it wi]ll lead you close to a w-shaped group Cassiopeia. Across [the] pole from Ursa Major and equally distant from Polaris [i]s this group that represents, some say a big chair upon [wh]ich the ancient queen of Ethiopia is seated.

In the course of night Ursa Major and Cassiopeia circle [the] heavens like the opposite sides of a wheel. At 9 p.m. May [t]he Great Dipper hangs upside down, Cassiopeia resembles [a] right side up on the opposite side of the pole. As the [ea]rth turns, Cassiopeia climbs the northeastern sky while [th]e Great Dipper drops down to the northwestern horizon. At [mid]night in middle latitudes, their positions are reversed by a [qua]rter turn. At 9 a.m. they hav exactly changed places. But [the] next evening the Great Dipper is again high overhead, and [Cas]siopeia hangs just above the horizon

Cassiopeia is a typical constellation. It is group of stars [th]at to us looks always the same. In fact, it appeared the [sa]me more than a thousand years go when it first received [th]e name and even longer ago than that when people first [obs]erved it. Yet some of the stars in this constellation are [n]earer to us than others, and all of them are separated from [on]e another by millions of miles. From some other corner of [the] universe these same stars would not form the same picture. [In] this same corner of the universe at some other time their [arr]angement will be different. For all the stars are really [spe]eding through space. The speeds and directions of hundreds [ar]e known. They are so distant f om the earth that it takes

several thousands of years for any change in their m ment to be noticeable to the naked eye. Nevertheless in ern instruments their motion can be detected over a p of years, and we know that a time will come thousand years in the future when many of the familiar star figures be hard to recognize

Some of the star groups are truly related. Five of the bri stars in the Big Dipper for example belong to the s family The "open cluster" of its members moves as a gr through space all the stars sharing a common speed and rection of motion.

For a lifetime of a man upon the earth through the pass of many generations during the years of a millennium, sky will look much the same. So the 89 constellations which the sky has been divided today will be there tomorr and will serve as points of reference for men a thousand ye from now Cassiopeia is just one of these 89 yet it is typica the rest Its borders include not just the w-shaped figure t is so easy to see with the eye, but many faint stars near that one must look closely to find. Then too, there are double stars that lie within this constellation area which only revealed as double in the telescope Here too are clust of stars and hazy patches of light that are called the nebul Stars that vary in their light can be found in this area also one night one can learn to find the "w" and to recogn Cassiopeia seated upon her throne Many nights must p though before one can easily pick out the boundaries of t "star state and find with his unaided eye all the stars t belong within it. Many more nights may be spent in discov ing those hidden objects that lie within the reach of the t scope

Near Cassiopeia is the section of the sky which the Gre named after Cassiopeia's son-in-law Perseus. A straggl stream of stars that runs from Cassiopeia to the little gr of the Pleiades depicts Perseus He still holds in his hand t head of the Medusa relic of his heroic adventure with t Gorgons. One of the wicked eyes of the snaky haired mons still shines but seems to close now and then For in Perseu a "blinking star" that changes its light from day to day Al it is called named by the Arabs the Demon star Anoth variable star in Perseus is Rho (ρ)

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So many constellations are figures in Greek mythology that ... with the stories adds to one's pleasure in astrono... You remember how Cassiopeia, Queen of Ethiopia, was ... beautiful and vain. She aroused the jealousy of the Sea ... ymphs and aggravated them into action. They went to Nep... demanding her punishment. Neptune ordered Cassiopeia ... take her daughter Andromeda to the seashore and chain ... r to ... rock. Then a huge sea monster would have devoured ... r, but Perseus happened along on his way from slaying the ... gly Gorgons. He glided down on his winged horse, Pegasus, ... ok the Medusa's head out of his pouch, turned the sea mon... r to stone, and rescued the lovely lady. Then he restored ... r to her chastened mother Cassiopeia, and her grateful ... ther Cepheus. All these are in the same part of the sky. ... ssiopeia, Cepheus, and Perseus are circumpolar in mid... itudes. Andromeda, Pegasus, and the sea monster are very ... ear at hand.

Some persons do not care for mythology; they are more ... terested in the rich historical and geographic heritage of the ... ies. They recount the adventures of South Sea Islands sailors ... to follow the stars for thousands of miles over the trackless ... eans. Or they point out that the Crow Corvus, is known as ... Corbeau in French, Corvo in Italian, Rabe in German. The ... Hebrews called it Noah's Raven flying over the deluge. To ... e Arabs it ... as the Raven's Beak and to the Chinese a Red... rd. So the stories of the stars take one over the world and ... ck through time.

In Cepheus is one of the most famous of variable stars, ... ta (δ) Cephei. By the way, when you use the Greek letter ... r the star it is customary to use the genitive case of the ... n name of the constellation following. Thus it is Beta

several thousands of years for any change in their move-ment to be noticeable to the naked eye. Nevertheless in modern instruments their motion can be detected over a period of years, and we know that a time will come thousands of years in the future when many of the familiar star figures will be hard to recognize.

Some of the star groups are truly related. Five of the bright stars in the Big Dipper, for example, belong to the same family. The "open cluster" of its members moves at a great pace through space, all the stars sharing a common speed and direction of motion.

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Persei instead of Perseus Delta Cephei and Alpha Ur Minoris. *It is simple after you have once discovered wh the system is. It is really a kind of universal languag th people interested in the stars all over the world can use an* understand, an astronomical *Esperanto* if you will, a kind sign language that all nations can understand.

Of course people who live south of the equator will n choose the Big Dipper as their guide to the night sky—b rather the Southern Cross. Wherever you live there are famil stars that remain in view night after night. These are the on on which to begin. Then as the seasons roll on *your explor tions can branch out to include the new visitors of spring an summer and the changing stars of autumn and winter*

3 Autumn and Winter Stars

) days start to grow short and leaves fall from the trees, e nights of autumn grow longer and winter arrives. Then a greater number of bright stars appears and the best of e meteor showers visit the earth. A knowledge of the con-stellations is a great help in reporting these shooting stars.

On September evenings a brilliant triangle composed of ree of the 20 brightest stars in the heavens passes overhead. ega, the blue-white sun in Lyra, the Harp is one of these d is the fourth brightest star in the whole of the sky nown as Alpha in the constellation of Lyra, it has as its ighbors four tiny brilliant jewels set in a parallelogram. One its neighbors, Epsilon ( ) is a double star when examined osely Between Beta and Gamma lies the magnificent Ring ebula, within reach of a small telescope.

The second of the three stars in the big triangle is Deneb, e brightest star in the Northern Cross. Although the Cross easy to recognize, the ancients visualized the same stars as cturing a Swan, and the proper name of this sky area is ally Cygnus. The stellar area enclosed within the boundaries f Cygnus houses many interesting objects. There are 61 ygni, the first star to have its distance measured Beta Cygni, lbireo, one of the most beautiful of the double stars within each of a small telescope and the Coalsack that looks like a reat cavernous hole in the sky

The last corner of the triangle is marked by Altair principal ar of Aquila, the Eagle. Altair shines in the Eagle head nd Deneb shines in the tail of the Swan. Thus the Swan flies one direction down the Milky Way while the Eagle wings is flight in the opposite direction. Easiest thing to do on hese nights of fall is to pick out the three bright stars and earn them the star pictures of which they are a part.

After that, ther are many other near-by constellations that e easy to identify There the tiny group of Delphinus, the olphin, below one arm of the Cross and over the head of e Eagle. Only five stars can be seen readily in this little roup which some people call Job Coffin. Even so, one can nd here several interesting objects with the telescope. Gamma

is a double star in the Dolphin's head, and behind his tail hazy patch which in the telescope is a cluster of con... stars.

Between Delphinus and Albireo at the head of Cygnus the image of an arrow. The constellation, made of five fa... stars, is labeled Sagitta. Between Sagitta and Cygnus lies even more inconspicuous figure Vulpecula, the Little F... from Aesop's fables. Prize object in this area is the Dumb... Nebula—an oddly shaped telescopic patch of misty light.

Sagitta and Vulpecula require real searching. So save th... for the time when you are looking for new fields to conq... and feel an irresistible urge to find something that y... fellow star gazers have not yet discovered. Actually of cou... Cygnus and Aquila, Delphinus and Lyra are remnants of ... nights of summer. They are crossing the south in the e... evening in early autumn. As the hours pass they will sink ... the west and disappear before the dawn. Driven before th... will go the stars that hung in the west in the early eveni... There are Boötes, off the curve of the Dipper's handle, ... Corona, Hercules, Ophiuchus, and Sagittarius.

When trying to describe the location of one constellati... in relation to another, we must have some method that w... always work. At first it might seem as though the easiest thi... would be to say to your fellow astronomer, "When you fi... Orion, Sirius will be just below and to the left." This mi... apply when Orion is on the meridian and your friend in t... northern hemisphere. However, it would be incorrect 3 hou... earlier or 3 hours later on the same evening in the same loc... ity, and it would be just the opposite in the southern hem... phere. In the long run, it is not wise to use the terms *above, below, right* or *left, up* or *down* when giving directions in t... sky.

It is far better to start out correctly. Imagine the sky a ho... sphere overlaced with circles like a spherical birdcage. A... the *hour-circles* pass through the poles, but other circles ... right angles to these are parallel with the equator and a... called *parallels of declination*. There is one hour-circle that ... very easy to visualize—the *meridian*. When you face d... south you can imagine it running from the horizon throu... the *zenith* or overhead point, on to the north celestial pol... and down to the horizon. (Out of sight it continues on throu... the south celestial pole as the *a... meridian*.) Suppose the... *that* Orion seemed to be just over the south *point on th... meridian*. To describe Auriga properly you would say th... it was *north* of Orion. It is between the head of Orion and t... north celestial pole. However, I ... of ... cause the great circle that started ...

ugh Auriga strikes Lepus beyond Orion on its way toward the south celestial pole.

Through the belt of Orion runs the celestial equator. Every star between the equator and the north celestial pole is said to have a declination north. Objects between the equator and the other pole are said to have a declination south. Just as the whole sky is overlain with lines through the poles similar to the meridian, one for any star anywhere, so at right angles to the hour-circles may be imagined other lines parallel to the equator—parallels of declination. Every star everywhere has such a parallel of declination.

All the stars that we can see have long since been carefully plotted on the framework of hour-circles and parallels of declination. This framework can be used by an observer any place on earth and any time of day or night.

The declination of an object is measured in degrees north or south from the celestial equator. If the figure has a plus sign before it, you know the object is north; if it has a minus sign before it, you know the object is south. Thus Capella in Auriga has a declination about +46 while Alpha Leporis has a declination about —17

In describing celestial directions it is safest to use the terms north and south only in this connection, (always in reference to directions on the sphere, not in connection with the cardinal points of the compass as applied to the horizon). From a star's place on its hour-circle its distance north and south of the equator can be described. To tell its place east and west along its parallel of declination we must have a similar point of reference. The vernal equinox is that point—the place where ecliptic and equator cross and which the sun passes about March 21. The east-west position is called right ascension and measured from the vernal equinox in hours. The distance is measured *eastward* from this equinox to the point where the hour-circle that goes through a star crosses the equator. Obviously the right ascension of a star which is given in hours, is similar to geographic longitude, while the declination of a star is similar to geographic latitude and is given in degrees.

Each star has a permanent place on the celestial sphere, where it can always be found. For instance, Betelgeuse (Alpha in Orion) is located near right ascension 6^h declination +7.

However this is more than you need to describe how to find Sirius in relation to Betelgeuse. First find the two stars, connect them with an imaginary line and note the line's direction *with respect to the hour-circles and parallels of declination.* It will be seen that Sirius lies south of Betelgeuse and to the east, on the celestial sphere while Aldebaran lies to the north

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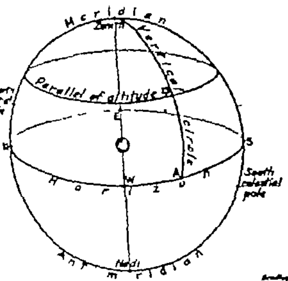


Figure 6 Our Meridian

locating objects on the celestial sphere is that employing altitude d azimuth—the coordinates of the horizon system. Altitude is the ght of the object above the horizon as measured along the vertical cle, A to * where * represents object. Azimuth is the distance of e object, measured either along the horizon or "parallel of altitude m the meridian to the object's vertical circle. In astronomy it is asured from south point westward (S to A) but in navigation it is asured from north point eastward (N through E and S to A)

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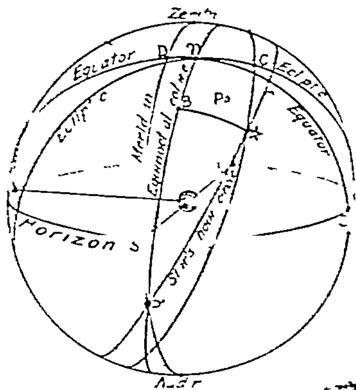


Figure 5. This Must Be Done—

But it is worth studying! The diagram representing the celestial sphere with the earth at the center shows the coordinates of the equator system, and of the ecliptic system. We have chosen a star (*) which has the following coordinates as measured along the lines of the diagram:

♈—Vernal equinox
E*—Right ascension
A*—Declination
♈C—Celestial longitude
C*—Celestial latitude
CTA—Obliquity of ecliptic
DWE around the circle to A—Hour angle
P,P—Celestial poles
N,E,S,W—North, east, south, west—cardinal points

Arc from D on equator westward around the circle to ♈—Sidereal

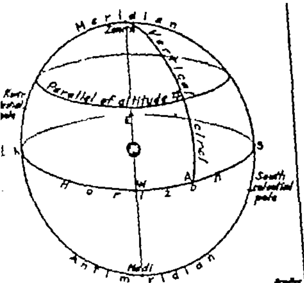


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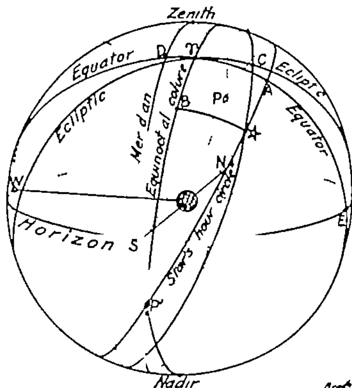


Figure 5 This May Be Difficult

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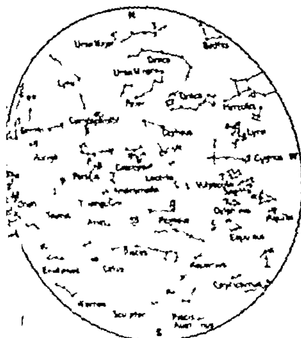


Figure 3 Chart of Autumn and Winter Skies

The map above shows the accepted geometrical patterns of all the constellations visible at 9 p.m. November 6 in latitude 40 N. Chief stars listed for study in the chapters on "Double and Multiple Stars" and "Variable Stars" are indicated, as are the first-magnitude stars, which are the following:

α Geminorum—Castor	Tauri—Aldebaran	Aquilae—Altair
β Geminorum—Pollux	Lyrae—Vega	Piscis Austrini—Fomalhaut
α Orionis—Betelgeuse	Cygni—Deneb	Aurigae—Capella

[illegible], the sun's place was in Aries on the first day of spring. Since then, Aries has been called the first sign of the zodiac, even though precession of the earth's axis has slowly caused a shift in the place of the sun at the time when spring [illegible].

In modern times, the sun is seen against the background of the Fishes, when it crosses the equator about March [illegible] is the vernal equinox, a reference point

for navigation—but for most astronomical purposes the ascension-declination system is more in use.

Off in the east of the sky early on the nights of autumn Pegasus, Andromeda Triangulum, Aries, Pisces, and Aqu —properly the stars of fall. Most characteristic of all th groups is the great square of Pegasus. To the ancients he r resented the white winged horse that inspired the poets of and carried Perseus through the sky after he had slain Medusa. To a modern boy however this section of the looks like a baseball diamond. There are the home plate, fi second and third base, even the right and left field foul-li and the catcher

In the old story Perseus was riding upon Pegasus when looked down upon the shores of Ethiopia and there Andromeda chained to the rock Appropriately then, constellation of Andromeda lies very near to Pegasus. In fa they share one star in common, Alpheratz, frequently m tioned by Anne Morrow Lindbergh in *Listen the Wind.* A dromeda was the daughter of Cassiopeia and Cepheus finally the wife of Perseus Since they are all close together the heavens, it is easy to find them and to remember them.

The corner stars in the square of Pegasus are so bright the area inside the square looks quite like empty sky On clear night, though a person with good eyesight can co well over half a hundred stars inside the square With telescope he can see many more. Some of these are doub and some are grouped in clusters.

When you are searching the square of Pegasus for the st that you can recognize look along Andromeda for a fa patch often called Messier 31 When you have finally loca this misty patch just barely visible to the eye it is hard believe that it is actually made of 100,000 000 000 suns the one that we see each day It s so distant that only telescope and camera combined can show its true nature. Th reveal it to be a whole universe of stars like the Milky W galaxy of which we are a part. While you have your telesc there be sure to turn it toward Gamma Andromedae for star is a beautiful double that can be easily separated with small telescope.

Once familiar with Pegasus and the long line of Andro eda you will have no difficulty in recognizing the v shap group of Pisces to the south, as well as the two smaller co *stellations, Triangulum* and Aries, in this same *region.* T Triangle lies just south of Gamma *Andromedae* and Ar hangs an equal distance south of Triangulum. The star Gamm in Aries is also a double easy to resolve Much more importa however is the fact that long ago w m zodiac

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Just as there are two Dogs so are there two boys, Castor and Pollux. The Twins belong in the zodiacal constellation

from which the positions of all celestial objects are reckor

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4 Spring and Summer Skies

THE LION, is one of the 12 zodiacal constellations and g the most ancient of star groups. Its sickle-shaped head triangular tail are easy to identify as it crosses high over outhern horizon early in the evenings of April and May easy way to locate it is to find the Great Dipper in the h and follow the pointer stars in the opposite direction the pole star. Down through the bottom of the Dipper l, an imaginary line will lead right to the head of the and on to the brilliant star Regulus in his heart.

t is said that this group received its name because the sun was here when the early Egyptians watched for the ndations of the Nile. At this season the lions came down drink, so a likeness of a lion was pictured in the stars. The ghtest star in the group, Regulus, is one of the nearer ghbors of the sun, but it is less than one-tenth as bright rinsically as our star. It is the faintest of the first-magnitude rs. Because it is one of the 20 brightest stars, is prominent the zodiac, and is especially close to the ecliptic, it has been refully plotted and constantly watched for centuries.

Hipparchus, in comparing the skies of his day with charts de hundreds of years before his time, discovered that gulus and certain other stars appeared to have changed their sitions. Not the stars, but the framework of reference im- ed upon them, had shifted. This westward precession has w carried the autumnal equinox along the ecliptic to a int in Virgo just south of the Lion tail. Leo pos- es a blue second-magnitude star Denebola, or Beta nis, in the tail, and one of the sky's finest doubles, Gamma, the sickle. The yellow-and-green stars of which it is com- sed can be seen with 3-inch telescope. A larger glass than is necessary to give proper separation to the triple com- nents of Alpha, for although Regulus itself is first magni- le, its companions are eighth and thirteenth magnitude.

Gamma in Virgo is also a double with an eighth-magnitude mpanion—one easily visible in a 3-inch glass. The same ope will find rich field of clusters and nebulae between d Virgo. ...chel was so impressed with the multitude

Gemini one of the 12 star groups along the ecliptic. Ca
and Pollux are much closer together than Sirius and Proc
since about 4 separate the first pair but four times t
distance separates the latter

Of course, this is just the way they appear on the celes
sphere when seen from the earth. From some other pla
their arrangement would seem different. Actually millio
upon millions of miles lie between the Twins, and one
nearly twice as far from us as the other Describing the
relation to each other in degrees is just like drawing th
places on a map One point upon the map may represent
mountain 18 000 feet high while another point upon that
paper may represent an ocean depth many miles below s
level So a map of the sky represents the stars as we see th
and gives no indication of the fact that some may lie 10,0
times as far away as others.

Gemini could be called the "Times Square" of the sky f
like the cross-roads of the world it entertains all kinds
visitors. On its way around the zodiac, each month, the mo
passes through its boundaries. Once each year at the su
mer solstice the sun passes near Eta Geminorum, and summ
begins in the northern hemisphere Shooting stars each ye
in December seem to radiate from Gemini Close beside E
in 1781 Sir William Herschel discovered a new world, t
planet Uranus. Beside Delta Geminorum, in 1930 Cl
Tombaugh finally identified a tiny speck upon the photograph
plate as the ninth planet in the sun s family—Pluto Dout
stars, variable stars, clusters, nebulae can all be located with
the boundaries of this constellation area.

No wonder then, that the nights of winter in the northe
hemisphere offer great reward to the star-gazer The bright
stars, the most spectacular constellations, the longest nights
all these serve to make the cold season ideal for observatio
of the stars.

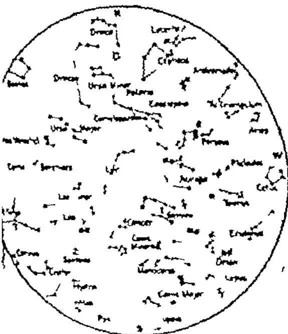


Figure 8. Chart of the Spring Skies

[illegible] map above shows the accepted geometrical patterns of all the [illegible]stellations visible at [illegible] on March 6, in latitude 40° N. Chief stars [illegible] for study in the chapters on "Double and Multiple Stars" and [illegible]riable Stars" are indicated, as are the first-magnitude stars, which [illegible] the following:

[illegible]rigae—Capella	Geminorum—Castor	β Orionis—Rigel
[illegible]onis—Regulus	β Geminorum—Pollux	Canis Majoris—Sirius
[illegible]uri—Aldebaran	Orionis—Betelgeuse	Canis Minoris—Procyon

[illegible]he best known zodiacal group of the summer months. With [illegible] brilliant red star Antares, and its long curving tail, the [illegible]rpion is easy to recognize. Antares is a giant sun 400 times [illegible] diameter of our own and tremendously distant from us. It [illegible] well known to the ancients, and modern astronomers [illegible]ve found that it has [illegible] tiny green companion. Antares is [illegible]casionally hidden by the moon and, when such an occulta[illegible] occurs, is a startling sight to observe with the telescope.

of the telescopic objects there that he called the regio "realm of the nebulae"

The only first magnitude star in Virgo is Spica. A blue-sun of great brilliance. Spica is so far away that its requires 192 years to travel across the space that separa from the earth Since light travels 186,000 miles a secon trillion miles a year it is obvious that Spica must be brig than the sun but unbelievably farther away It has a tiny ible companion which was discovered while analyzing its with a spectroscope.

Cancer the Crab is the next zodiacal group west of During the month in which the sun appears to pass t this section of the zodiacal band, the Crab is, of co invisible. It is inconspicuous most of the year as for only faint stars compose the figure. A misty p in the center of the constellation is called Praesepe. It is re a cluster of thousands of suns so distant that only on a night can they be seen with the naked eye only with a telescope can they be separated, even at the edge of the gr

Between Cancer and the horizon can be found a l pentagon of stars that picture the head of Hydra, the serpent. The most extensive constellation of the whole Hydra winds beneath Cancer Leo Virgo and Libra. A *120 one-third the way around the heavens, the span* serpent stretches. Yet over its whole length it has but bright star a second-magnitude one in its heart. Cor Hyd the Heart of Hydra, is properly called Alpha Hydrae, another name is Alphard.

Several small constellations are arranged along the b of the serpent. Close to Alphard in fact lying directly tween Alphard and Regulus, rests Sextans. A little fart to the east Crater the Cup balances on the serpent's b south of Denebola in the Lion s tail Still farther toward tail, close to Virgo perches Corvus, the Crow Corvus, the way is a convenient little group to know If you want to locate the Southern Cross, just find Corvus, and C is directly south of it. One can always find Corvus by star with the Great Dipper following the curve of the Dipp handle south to the bright star Arcturus, continuing on ab the same distance to sparkling Spica and then south agai equal distance to Corvus.

Next group along the zodiac east of Virgo is Libra, Scales, once represented as a balance of justice The conste tion is almost a square, or diamond between Scorpius a Virgo Alpha in Libra is a double star separable with fi glasses, while Beta is the only bright green star in the heave

Far more spectacular than either of its neighbors, Scorp

er Carrier is the next group along the zodiac. On the ks of the Babylonians it was represented as a man with a er jar, although the Arabs imagined it a mule carrying er barrels. There are no bright stars in the whole area and group is not easy to identify. The easiest way to locate it to find Fomalhaut, first-magnitude star just south of it the corner of Pegasus just north of it. Then with considerable imagination you can trace out the water jar, the holder the jar and a stream of water pouring into the mouth of Southern Fish, Piscis Austrinus.

Most prominent of all the spring groups, Leo can be seen the early evening from March to June. Succeeding it dies dominates the early evenings of July and August with Crown in Hercules close by. Directly south of Corona, ... is the outstanding zodiacal group for the summer ... The appearance of Capricornus above the southern horizon signifies late night hours of summer or the evening ... of the coming fall to observers in the northern hemisphere. When Fomalhaut crosses the south in the early evening, summer is over ... high above the great Square of ... warns us of the presence of autumn and the approach winter. When once more the winter stars rise out of the ... in early evening the spring and summer groups have run course and drift out of sight in the west after each night.

So as the seasons roll the patterns of the stars are a constant reminder of the journey of the earth round the sun, as represented by the apparent circuit of the sun around the zodiac. ... and fascinating, this endless wheeling of the sky is ... of the inevitable progress of time. Year after year, century after century the earth pursues its timeless course, ... the heavens bear mute evidence to its motion. Few things ... are that are as dependable as the shift of the stars with seasons, the rising of the sun, the passing of the days.

Each constellation group that reflects these heavenly changes ... a window frame through which one may look to the ... borders of space. Bright stars comparatively close to the ... compose the outline, but off in the distance are others ... brighter but faint to our eyes because of the vast space ... the constellation outline may be ... red star or a ... blue one perhaps ... cluster of suns or ... twin star. Some... passing close ... hand much nearer than the nearest star ... may appear ... to belong to the star group ... shooting star may seem to fall from that familiar section. ... are but passing ... framed for the moment on that ... of the sky. A planet, too, may swing this way and for ... seem one with the other members of the constellation, ... as it moves on in the confines of its orbit, another con

ly affected by time. Each of its members a sun moving
gh space, perhaps alone, perhaps in company with other
bers of the family—that sun in time will leave some of
ighbors far behind. The familiar figures, slowly shifting
gh the centuries, will one time dissolve their present
pes as their members become absorbed into new patterns.
t through all the memory of one man the constellations
more constant than the rock of Gibraltar. They offer a
k-post to time, direction, season. They present a passport
latest and mysterious regions of space.

[illegible]heast of Alpha Crucis is the well-known Coal-sack [illegible] which looks like a great black hole in the sky. When [illegible] Herschel saw the first of these objects on his survey [illegible] northern skies he was much impressed, and it is said [illegible] he called his sister to the telescope to see the "hole"—a [illegible]dow into outer space. It was to be expected that his son, [illegible] exploring the southern skies, would label any similar [illegible] by the same name. But modern astronomers dis[illegible] with the Herschels and no longer regard these dark [illegible] that are scattered so generously in the Milky Way as [illegible]. Probably they are great dark clouds of dust and gas [illegible] absorb the light of stars that must lie beyond them. Some[illegible] the dark nebula beneath the arm of the Cross is [illegible] as the Black Magellanic Cloud.

Two other features of the southern skies bear Magellan's [illegible]; they are two hazy patches like detached portions of the [Mi]lky Way. There is nothing like them in the northern [illegible], and Magellan's expedition reported them to northern [illegible] among the curiosities seen in the other half of the [illegible]. Since then they have always been called the Greater [an]d the Lesser Magellanic Clouds. Also known as Nubecula [M]ajor and Nubecula Minor, they are among the first sights [o]f which one searches the southern skies.

The Greater Cloud is about 7° in diameter, nearly 14 times [th]e full moon; the Lesser, not even 4° in diameter, covers an [are]a not as large as Crux. A full moon occasionally brightens [th]e sky so that it is a little difficult to locate the smaller cloud, [bu]t even then the large one can be found with ease.

Examination of these two clouds has shown that they are [ma]de of all types of celestial objects that exist in our Milky [W]ay. There are bright stars and faint ones, red stars and blue [one]s, large suns and small ones, variable stars, star clusters, [illegible] nebulae, dark nebulae—a complete array. The Clouds [of] Magellan are island universes and close neighbors of the [Mi]lky Way galaxy which is our home. The small cloud is [ab]out 84,000 light-years distant, the large one about 75,000 [lig]ht-years. When one recalls that light travels 186,000 miles [a] second and traverses 6 trillion miles in a year, then these [illegible] families of stars seem far away. Photography brings [illegible] a haze of stars around them, and their distance apart is [ab]out 30,000 light-years.

The Magellanic Clouds are irregular in shape and present [a] straggling appearance that contrasts sharply with the great [spi]ral in Andromeda and other island universes. Some 3000 [v]ariable stars have been recognized in the clouds, among them [illegible] which enable astronomers to measure their distance [illegible] [L]arge Cloud is rich in super-giant stars, and 30 globular

5 Stars of the Southern Sky

MOST OF THE ancient observers of the sky lived in the n ern hemisphere, so south of the equator the heavens reversed. The constellation of Orion depicts a man stan on his head the familiar Scorpion waves his tail in the and even the Big Dog balances on his nose. Of course inversion of the constellations does not occur all at once they shift slowly overhead as one travels on the surface of earth.

Suppose a traveler leaves New York City for the south. he journeys toward Florida the stars in the south rise hig those in the north drop closer to that horizon If it were evening in May he would have his first glimpse of the Sou ern Cross off the tip of Florida. By the time he reac Havana he would find it well in view If he should go to equator he would see the cross one-third of the way up sky and at Lake Titicaca Peru, half way from horizon zenith. His journey on through the southern hemisphere wo carry it higher and higher

This same Southern Cross is a guide to the south celes pole. Like the Great Bear in the north, it indicates the locat of the pole and therefore is often employed by navigat seeking to establish their place upon the earth. In May June it can be found early in the evening above the south horizon clearly outlined by four stars of almost equal b liance. Alpha is at the foot of the figure nearest the so pole. Gamma is at the top Beta and Delta in the arms. Gam is a reddish star bright to the eye but faint on the blue-sen tive photographic plate Kappa is also a reddish star and that appears fainter on the photographic plate than in the s Surrounding Kappa, though, are over 100 stars in a cluste

From top to bottom this Southern Cross, Crux, measu 6 —no taller than the distance between the pointers of t Dipper It covers, in fact, an area about one half that of bowl of the Dipper—about [illegible] of the sky But while wi the Dipper's bowl only nine stars are visible there are wi the boundaries of the small constellation Crux 32 stars wit reach of the naked eye.

Southeast of Alpha Crucis is the well-known Coal-sack bula which looks like a great black hole in the sky. When lliam Herschel saw the first of these objects on his survey the northern skies he was much impressed, and it is said at he called his sister to the telescope to see the "hole —a ndow into outer space. It was to be expected that his son, hn, exploring the southern skies, would label any similar rk lanes by the same name. But modern astronomers disree with the Herschels and no longer regard these dark eas that are scattered so generously in the Milky Way as oles. Probably they are great dark clouds of dust and gas at absorb the light of stars that must lie beyond them. Somewhat the dark nebula *beneath the arm of the Cross* is known as the Black Magellanic Cloud.

Two other features of the southern skies bear Magellan's name; they are two hazy patches like detached portions of the Milky Way. There is nothing like them in the northern avens, and Magellan's expedition reported them to northern opies among the curiosities seen in the other half of the world. Since then they have always been called the Greater and the Lesser Magellanic Clouds. Also known as Nubecula Major and Nubecula Minor they are among the first sights which one searches the southern skies.

The Greater Cloud is about 7 in diameter nearly 14 times e full moon, the Lesser not even 4 in diameter covers an rea not as large as Crux. A full moon occasionally brightens sky so that it is a little difficult to locate the smaller cloud, it even then the large one can be found with ease.

Examination of these two clouds has shown that they are ds of all types of celestial objects that exist in our Milky ay. There are bright stars and faint ones, red stars and blue es, large suns and small ones, variable stars, star clusters, eous nebulae, dark nebulae—a complete array. The Clouds f Magellan are island universes and close neighbors of the Milky Way galaxy which is our home. The small cloud is about 84,000 light-years distant, the large one about 75 000 ght-years. When one recalls that light travels 186,000 miles second and traverses 6 trillion miles in year then these ating families of stars seem far away. Photography brings a haze of stars around them, and their distance apart is bout 30,000 light-years.

The Magellanic Clouds are irregular in shape and present straggling appearance that contrasts sharply with the great ird in Andromeda and other island universes. Some 3000 ariable stars have been recognized in the clouds, among them those which enable astronomers to measure their distance. Large Cloud is rich in super-giant stars, and 30 globular

clusters have been recognized there. In the Greater Clo S Doradus, a super-giant variable, 500,000 times as brigh the sun Some 180 000 000 miles in diameter it is, except some super-novae, intrinsically the brightest object kno There too, surrounding 30 Doradus, is the Great Loo Nebula the largest known gaseous nebula in the univers

After you have found the Southern Cross and picked the Clouds of Magellan the next objects to attract atten are Alpha and Beta Centauri First and second brightest s in Centaurus, they are often called Guardians of the Cros you draw an imaginary line through Delta and Beta Cr (along the cross-bar of Crux) it guides you to these br stars in Centaurus. The constellation, which represent figure half-man and half horse is one of the largest in southern sky It is nearly 45 in length almost half distance from the horizon to the zenith

A particularly interesting and magnificent star is Al Centauri. Not only is Alpha Centauri the third brightest in the heavens, but it is our nearest binary system. The co ponents of Alpha (A and B) occupy 80 years for a revolut around each other More than this Alpha happens to b multiple star composed of the binary and a third, f companion (C) The l tter Proxima Centauri, is visible the telescope—with magnitude about 10 5—and is the nea neighbor to the sun being about 4¼ light years away though Proxima is over 2 away from Alpha and its comp ion B yet it is connected gravitationally with the latter sys and is moving through space ne rly parallel to it actually an enormous curve around Alpha with a period prob over 300,000 years

Another object in Cent uru for which the amateur tronomer alw y look i Omeg (ω) Centauri a hazy pa of light that is the brightest t the gl bular lusters. Th cluster 18 northwest of Alph C nt ur is a fine sight w field-glasses and even more be ut ful with the telescope. It composed of some 50 000 t r mere th 100 of which a variable Brightest d ne st f the 100 or so globel clusters known th one som 0 000 l ght y ars dist from the earth

After a casual glance at the t ll t m n th south, o is struck with a differen e n the constell t n figures a names. Although there are s me old f hi d objects (I Ara, the Altar Columba, the Dov M sc the Fly Pa the Peacock Volans, the Flying F sh nd C r n Austra the Southern Crown—there are many more mod n figur One finds a Clock or Horologium a C mpas C i inus Furnace, Fornax an Easel, Pictor a Telescope, Tele

often confused with the real Cross, it is frequently cal[led the] False Cross. A line from the top of this figure to the [bottom] and prolonged five times that distance does not lead [to the] south celestial pole but off toward the Great Cloud of [Magel]lan. A navigator would find himself far from his dest[ination] if he should steer by the wrong cross.

Northwest of Crux lies Vela, but east of Crux ... Centaurus is Circinus, the Compass. Alpha Circini is the ... of the Compass, while Beta and Gamma are the two ... Not far away one can recognize Triangulum Austr[ale, the] Southern Triangle. This is a counterpart to Triangulum [in the] northern hemisphere just as Corona Australis is a s[mall] duplicate of the Northern Crown. The Southern Cr[own] near the tail of the Scorpion and not far from Ara, the ... and Norma, the Level. All these small constellations are [com]posed of second- and third-magnitude stars.

There is one extremely long constellation in the s[outhern] hemisphere, Eridanus, the River. It begins near Rigel in O[rion] very close to the celestial equator, traces its winding c[ourse] from Orion to Cetus, past Fornax to Phoenix, and ... Hydrus. The first magnitude star Achernar at the so[uthern] end of the River lies about 15° from the Small Mag[ellanic] Cloud and the northern end of this "Mississippi of the [sky"] is near the great nebula in Orion. Omicron Eridani is a [beau]tiful triple star well worth examining with a telescop[e. In] this same constellation is located an extraordinary ... great globe of dust and gas surrounding an e... magnitude star. If one traces the course of Eridanus ... nine constellations along its boundaries: Hydrus to the ... Orion, Lepus, Caelum, and Horologium to the east, T... to the north, and Cetus, Fornax, and Phoenix to the w[est].

The Toucan houses the Lesser Magellanic Cloud a[nd the] globular cluster 47 Tucanae. Some 20 000 stars in the c... blend together to appear as a single star of fourth magn[itude]. Hydrus encircles the other border of the Lesser Cl[oud of] Magellan. Between Hydrus and Dorado, the Swordfi[sh, lies] the Greater Magellanic Cloud and the tiny constel[lation] Reticulum. Between Dorado and Carina can be found ... and Volans. Mensa, the Table Mountain, and Cham[aeleon] lie nearer to the south celestial pole than Dorado or C... Musca, the Fly, lies between the south celestial po[le and] Crux, while Apus is south of Triangulum.

East of the Scorpion's tail, Corona Australis, Telesc[opium], Ara and Pavo the Peacock are not far from the ... celestial pole. South of Capricornus, the Goat, and Aqu[arius], the Water Carrier, lie Piscis Austrinus, Indus, and Grus, nearer to the south pole than Cetus can be found ...

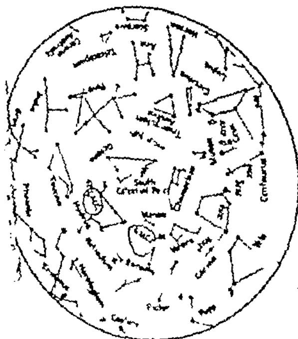


Figure 10 Chart of the Southern Skies

map above shows the accepted geometrical patterns for the constellations within 50° of the south celestial pole. All the stars listed study in this chapter are indicated, as well as the first-magnitude rs, which are

arinae—Canopus	β Centauri
ridani—Achernar	Crucis
entauri	β Crucis

nstellation names are the official ones in Latin, except Tucana, ed in English on the chart.

d the Toucan and Sculptor. Near the Hydra's head lie ppis and Pyxis, part of the old ship Argo. The rest of the p, Vela, and Carina are still closer to the south celestial pole. For the star-gazer who spends much of his time in the rth, it is interesting to know the relation of southern constellations to groups familiar in the north. For instance on

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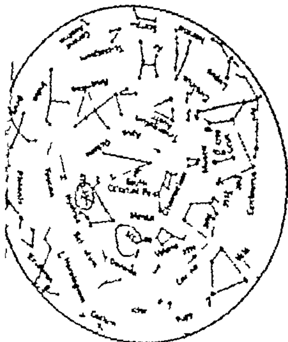


Figure 19 Chart of the Southern Stars

map above shows the accepted geometrical patterns for the con-
lations within 55° of the south celestial pole. All the stars listed
study in this chapter are indicated, as well as the first-magnitude
s, which are

—Canopus
—Achernar
entauri

β Centauri
Crucis
β Crucis

stellation names are the official ones in Latin, except Toucan,
n in English on the chart.

d the Toucan and Sculptor. Near the Hydra's head lie
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, Vela, and Carina are still closer to the south celestial pole.
For the star-gazer who spends much of his time in the
rth, it is interesting to know the relation of southern con-
llations to groups familiar in the north. For instance, on

the same hour-circle to the south of Aries lie Fornax, Eri- Horologium and Hydrus. In order too from Taurus to south celestial pole, are Caelum, Dorado and part of Me South of Gemini, bordering right ascension 6h40m lie Pup Canopus in Carina, sections of Pictor Volans, and Mo South of Cancer can be discovered Pyxis, Vela, Vola Chamaeleon while along the same hour-circle with Leo Antlia, Vela, Carina and Chamaeleon

Beyond Virgo toward the south pole we encounter Ce taurus, Crux, Musca and more of Chamaeleon. The ho circle of 15h20m through Libra also cuts Lupus, parts Norma Circinus, Triangulum Australe and Apus. On the hour-circle through Scorpius can also be traced Ara, a bit the Southern Triangle and Apus, while near-by another o Sagittarius, then goes south through Corona Australis, Te scopium, and Pavo. South of Capricornus on 20h40m Microscopium, Indus, and a bit of Pavo while 2 hours east south of Aquarius, are Piscis Austrinus, Grus Tucana, some of Indus. A line through Pisces goes south to Sculpt Phoenix, and Tucana

In general these meridians have been selected as nea central as possible on the zodiacal groups and on the aver are 2 hours apart.

When one discovers that Crux lies south of Virgo, Greater Magellanic Cloud is in the same hour-circle w Taurus, and the Lesser Cloud in the same right ascensi with Pisces it is easy to find the other neighboring groups

Familiar and friendly to the people of the south, Cr Alpha and Beta Centauri, the Magellanic Clouds, and t rich star fields of the Milky Way are foreign and fascinati to the traveler from the north.

6 The Planets

[illegible] were five of them, and they moved about among the "fixed" stars. Men who looked heavenward were quick to call them the planets, which meant that they were wanderers.

They were different from the stars in more ways than one. Not only did they wander, always staying within the constellations that lie along the ecliptic, but they shone with a steady light that was somehow different from the twinkling of the stars. Early astronomers knew very little about them, and it was not until Galileo turned his telescope on the skies that they began to learn. After that, but very slowly (at the rate of approximately one every 100 years), astronomers began adding to the number of planets so that we now know eight in addition to the earth.

They are the sun's children, brothers and sisters of the earth, and all neighbors in the solar system. But they are not very close neighbors as judged by earthly standards. If, in constructing a diagram on the ground, we assume the sun to be stationary and make a mark a little less than 3 inches away from it, that mark might represent the position of Mercury, the nearest planet to the sun.

At 5.4 inches we would make another mark, for Venus; at 1 foot we could indicate the distance of our own earth. Mars would be 1½ feet from the sun, and then, between 2 and 4 feet, we would make a series of marks to represent the asteroids—the minor planets which are discovered elsewhere. We should have to pace off a bit more than 5 feet from the sun, though, to get to Jupiter's position, and 9½ feet for Saturn, and then walk out 19 feet from the sun for the position of Uranus.

Still on the same scale, Neptune would be a full 30 feet from the sun and the newly discovered Pluto would be 40 feet. The earth, remember, was only 1 foot from the sun, and that foot represented an average distance of 93,003,000 miles—the astronomical unit.

As for size, the earth is large to us with its 7918-mile diameter. Yet Jupiter, the largest of the planets, is more than 11 times the diameter of the earth, and the entire planetary

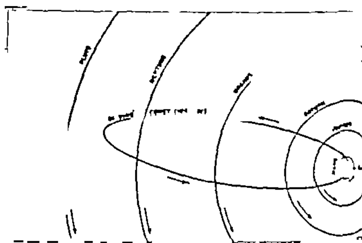


Figure 11 The Solar System

A plan view of the orbits of 7 planets. Drawn t scale with one co Di Vico's, included, the diagram gives an accurate impression of relative distances between the planetary orbits. The orbits are at mean distances actually in one place Pluto's orbit is nearer sun than Neptune s.

system of Mercury Venus, Earth Mars, Jupiter Sat Uranus Neptune and Pluto would have to be multiplied hundredfold to make a body as big as the sun.

And there we have roughly a picture of the plan system as known today although we have not included zodiacal light, comets meteors, and satellites. It is a pic drawn from the outside, of the planets as seen from a p over their orbits, and consequently a picture we can ne see from the earth For the observer here, with only his e to help him there are five blazing points of light (and perh a sixth dim one, if he knows where to look for it)

One of these points of light is elusive That is Merc which stays close to the sun like a child clinging to its moth apron strings. Because you must look for it so soon after set, or before sunrise, there was a famous astronomer Cop nicus, who never saw the planet in all his life There is al however the story of at least one amateur who has s Mercury not once but 150 times.

It s all in knowing how The planet is best seen as an "e ning star" in the spring, and as a morning star" in the f But there are *six* periods in every year when it is fairly placed for observation, these periods occurring when

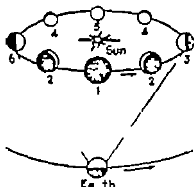


Figure 12. PLANETARY PH

Mercury and Venus, the inferior planets, go through similar to those of the moon gram shows

1—Inferior conjunctio
2 and 2 —Greatest brilliancy
3—Greatest western el tion (morning s
4 and 4 —Gibbous phase
5—Superior conjunction
6—Greatest eastern el tion (evening star)

For the planet Venus no exact rotation period, or day yet been satisfactorily determined, because of the imperma nent nature of the markings on its cloud surfaces. Rec spectroscopic studies indicate a period of a few weeks. Venus, however the heat that pours down on the sunlit si is less intense because of two factors—its greater dista from the sun, and its atmosphere which while it holds a gr deal of warmth distributes it evenly around the planet.

Venus and the earth might almost be called the twin si of the solar system The orbit of Venus, which the pla travels in 225 days, is nearer to a perfect circle than tha any other planet, and that of the earth is not far behind this respect. The two planets are approximately of the sa size Venus having a diameter of 7575 miles and the ea having one of 7918 miles, and they are closer together in sp than any other major planets.

Nearness and heavy clouds around Venus account for t appearance of the planet in the sky For Venus is not mod visible With the exception of the sun and moon she is t brightest object normally seen in the heavens and at her b outshines Sirius, the brightest of the stars by 13 times. So times when there is no moon to interfere she is bright enou to cast a shadow

And not only is she far more conspicuous than Mer she is also visible for greater intervals of t me Like the ot planet Venus is often out of sight on the other side of t sun but these periods of invisibility are not nearly so f quent as those of Mercury And unlike the smaller plan Venus can be seen for as much as 4 hours at a time mak her appearances in th same way as Mercury She slides do the celestial vault, trailing the sun in the evening, and wo

climbs into the sky before the sun in the early hours of ...ing.

In either case, turn a pair of binoculars on her. With a magnification of 10 diameters and upward you can see her go through phases like those of Mercury and the moon. Of the thin crescent is a striking sight, gleaming miniature of the moon ... crescent phase because at that time Venus is at brilliant ...

Both of the inner planets, paradoxically enough, do this ... and stand out most when only a small section of their illuminated surface is reflecting light to the earth. It's easily explained by noting that when they are in their "full" phase they are on the opposite side of the sun, which means, in the case of Mercury, an additional distance from the earth of over 72,000,000 miles and, in the case of Venus, one of 134,000,000 miles. The figures are the diameters of their orbits, if you care to check.

So they are brightest when near the earth. But not when they are at their very nearest, because then they are almost directly between the earth and the sun and the dark sides of the planets are presented to us. The greatest brilliance comes at a certain critical angle between the greatest elongation east or west and the point directly between the earth and sun, when the nearness of the planet and the width of the crescent combine to the best advantage. The crescent Venus appears ... times greater in diameter than the full Venus.

To return again to our field glasses and telescopes, Venus in her crescent phase offers ... low-power instruments ... turn ... telescope on the ... (and remember that thousands of amateur astronomers ... telescopes ... may be able to detect spots on the surface. It is ... for such an instrument, but can be done ... These spots, ... are not on the surface of the planet proper but (the upper ...) ... that surrounds Venus. ... saw "large ... spots" ... not permanent ...

The ... to astronomers ... because of ... the planet goes through one ... projected ... the sun, ... observed which is undoubtedly ... proof of ... there may be the other necessary elements ... on the surface our imagination may ... plant and perhaps animal life in the midst of such a

steaming swamp as characterized the earth's early ages we not know Absence of permanent markings prevents knowing Venus's rotation period. Indications are that it is a few earth weeks long.

Mars is an excellent subject for small telescopes. It shows its famous reddish color to the naked eye (a color which persists on its surface when viewed with large instruments and under a small telescope it offers opportunities to see details. Even so small an instrument as a 4- or 5-inch telescope will do under the right "seeing" conditions.

Under a telescopic magnification of 200 to 350 diameters grayish or greenish markings stand out against the red background. At less than 300 diameters the polar caps appear and so too does the dark wedge of Syrtis Major extending toward the north Other dark areas can be picked up as w and as telescopic power increases (try it sometime with a to 12 inch reflector) the number of features visible increases

There are several reasons why we know so much about Martian conditions and surface details. Mars has, of course, long been a subject of great popular interest, but many known facts would still be a mystery were it not for the unusual clarity of the planet's atmosphere Slight clouds—whether dust or some other composition—appear only infrequently and the Martian air is so transparent as to permit excellent opportunities for study of surface detail.

Then, too when the planet is in opposition—when the earth and Mars are in a straight line—it comes nearer, 34 000 000 miles, than any other major planet except Venus. At times Mars may be observed going through a slight gibbous phase although it never goes so far as to become a crescent or even as to enter the half moon" phase.

Mars differs greatly from the earth in size, having a diameter of only 4216 miles. In almost every other point, however, she compares favorably and as a result has become the home for life on one of the planets as conceived mind.

... this suspicion of life on Mars necessarily ... e world of science, for many reputable astronomers a majority of them—believe that there is at le... on the planet. And the existence of vegetation ... conditions which might possibly support some ... life.

... of life on Mars probably got its start wh... Schiaparelli observed strange ... and termed them canali, which ... He ...

a implication of artificiality of something which had been created by intelligent beings.

Percival Lowell observed these canals and expressed the belief that they were constructed by an advanced race of beings who dug them to bring water down from the poles. The character and extent of the canals is debatable, for to see them is a question of seeing detail at the extreme limit of visibility. Future telescopes may settle the questions about the nature for all time, although observers now report that they have seen sections near the canals turn blue-green in one season and dark brown in another.

Meanwhile, these are the known facts that figure in the arguments concerning life on Mars.

The atmosphere contains small amounts of oxygen and water vapor, which has been estimated quantitatively as ... as much oxygen and 5 per cent as much water vapor as are found in the atmosphere of the earth. The equatorial temperature could probably support life as found on the earth, for it rises to 8 F. The axis of the planet is inclined to the ecliptic at substantially the same angle as that of the earth, which combined with a similarity between the orbital motions and conditions of the two planets would result in roughly approximate seasons. These seasons are twice as long, however, as those of the earth because the year consists of 7 days—nearly twice that of the earth. The planet's day is nearly the same as the earth's, for it rotates on its axis in 24 ... 37 minutes.

The planet's polar caps vary in size with the seasons, too, a change which is synchronized with color changes in the regions such as Syrtis Major, thought by some astronomers to be a ... area of vegetation. The composition of these polar caps may be either frozen carbon dioxide or frozen water. Because color variations noted at the edge of the caps many scientists are inclined to believe that when they melt they turn into liquid and therefore are not carbon dioxide, which would instead ... the ... gaseous.

Mars is the first planet in the outward journey from the sun ... that ... which has any moons so far as we know. Th... ... tiny little satellites which were discovered by Asaph Hall ... the U. S. Naval Observatory in 1877. The ... are too small to be picked up with any but the largest telescopes, neither being more than 10 miles in diameter. But Phobos, the inner moon, runs three laps around the planet ... rising and setting three times each ... hours and rising, moreover, in the west and setting in the east. ... when it passes the slower Deimos, observers on Mars would

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Nor does this suspicion of life on Mars necessarily rea outside the world of science for many reputable astronom —possibly a majority of them—believe that there is at le plant life on the planet. And the existence of vegetation p supposes conditions which might possibly support some li of animal life.

The question of life on Mars probably got its start w the Italian astronomer Schiaparelli observed strange ma ings on the surface and termed them canali, which in language meant channels. He was misinterpreted, though the lines became known as cana

ject. The satellites often become lost against the background as in transit and may drop out of sight—even in large telescopes. The shadow being a black dot, is fairly easy to follow as it glides over the cloud surface of the planet (and may even change its shape at times because the surface it falls over is uneven). The satellites in transit require at least a 6-inch telescope, but the shadow thrown on the planet is visible with a 4-inch instrument at times.

Despite the fact that they seem to move haphazardly appearing, perhaps, all on the same side of the planet one night and scattering around it the next, the four moons of Jupiter form an orderly miniature of the solar system. Now and then one of them may vanish, and very rarely all four of them may be in front of or behind the planet. Yet each has a definite period (which you may time for yourself and then check with an ephemeris) each has a definite path and every one of these four travels around the primary in the same direction.

Of the 11 Jovian moons the outermost three revolve in an opposite or retrograde direction, from east to west. This has given rise to discussions as to whether they might not be captured asteroids and therefore not originally members of Jupiter's system. The four easily visible in small telescopes are considerably larger and brighter than the others. It is worth mentioning that Ganymede and Callisto of Jupiter's train, are bigger than the planet Mercury.

There is still another planet in the group that are classed as "naked-eye" objects, and although Jupiter may claim fame by its unrivaled system of moons, this other world—Saturn—has a set of rings that is unequaled in the entire universe. That is, our scientific caution prompts us to say the rings are unequaled so far as we know.

In the eyepiece of a small telescope, they surprise observers with their beauty even though it be expected. Composed of millions of tiny moonlets, the rings appear as a thin circlet poised some 7000 miles above the planet's equator. They are 41,500 miles wide from inner to outer edge, and by comparison with their width they are thinner than tissue paper, being not more than 10 miles thick.

This microscopic thinness causes the rings to disappear when viewed edge-on. At such times they are visible only in the most powerful instruments as a thin needle piercing the planet. At other times the rings may seem inclined upward or downward, for they are really inclined at an angle of 27° to the plane of the planet's orbit and lie in the plane of its equator. As Saturn moves around the sun we see them at varying angles—apparently from above, below or edge-on.

see both of the satellites racing each other across the s with respect to the stars beyond.

Mars, however is not unique in its set of moons. Jup carries with it a retinue of 11 satellites, four of which easily visible in small telescopes To look at Jupiter and satellite system we must let our gaze wander far beyond orbit of Mars and over the asteroid zone. The 4½ feet dista between the two in the diagram we planned at the begin of the chapter (fig. 11) was based on a scale in which ea foot represented 93 000 000 miles. Jupiter despite this grea distance, usually seems brighter than the red planet becau it is so much bigger and because it reflects nearly three ti as much as Mars does of the sunlight it receives.

Jupiter is the largest of the planets and curious astronom have timed its speed of rotation upon its axis at 9 hours a 55 minutes. As a result of this speed, there is a huge bulge the equator so great that the diameter of the planet ta through the equator is 88 698 miles, or nearly 4000 mil more than from pole to pole

A pair of binoculars or field-glasses shows a tiny disc magnification of 18 times will do very well, but is even mor than is needed With a larger instrument, Jupiter resolves in a series of red yellow tan and brown shadings, as well a wealth of other telescopic detail.

Exceptionally good "seeing" is not necessary to get a cle view of Jupiter's surface markings, and frequently a slig haze or smokiness in the air will help to steady the image. T cloud belts, for which the planet is famous, will appear in lo powered telescopes as parallel bands stretching across th disc. And another feature that the amateur will—or may— able to observe is the "Great Red Spot which was identifi on drawings made of the surface in 1859 and has disappear and reappeared during succeeding years. A marking of pe haps similar nature, discovered early in the twentieth centu and known as the South Tropical Disturbance may also observed.

But it is in its moons that Jupiter contains the greatest te scopic treasure for the amateur The four that are visible r a merry race with each other around the planet and chan their respective positions from hour to hour and night to nig They aren't hard to identify with an ephemeris, and they c be followed for hours as they speed in front of Jupiter thro ing their shadows on the planet vanish behind its giant d or plunge suddenly into its deep shadow Binoculars locate them if outside the disc.

It is easier to watch one of the moons throw its shadow Jupiter than to watch the moon itself in front of

according to the planet's position with respect to the e They reflect so much light that when they present their b est aspect to the earth Saturn in the sky seems three t brighter than when the rings are edgewise. And when are *edgewise (which occurs every 15 years) they are invi* in small telescopes nearly so for the very largest

A medium-sized instrument shows the divisions of the clearly The first one to resolve itself is the dark Ca division, which divides the system in two and is not har detect with a small telescope. On the outer of the two r thus formed, we may be able to pick up the faint, gray E division And the word "may" is used advisedly for Encke strip is elusive and not always visible. On the b ring there is a gradual shading off on the edge next the pl a shading which melts into the misty gray border of "crepe" ring. *This foggy curtain on the inside of the* system is comparatively transparent, and the shape of planet can often be seen through it. The stars, too becaus the tenuous nature of the crepe ring, can be observed shi through it on occasions.

Saturn throws a shadow across its surrounding belt, a sh black shape that outlines one rim of the planet and the ri in turn throw a soft, neatly bordered band upon the pla This latter shadow falls upon cloud surfaces similar to th of Jupiter cloud surfaces that are belted just as those of larger planet. But few details concerning them can be s *unless unusual observing circumstances prevail. Every* often a spot—probably related in nature to the Red Spo Jupiter—appears, but none with the permanence of Jupit marking has yet been observed. The most recent one wa *white spot which appeared in 1933*

Where Jupiter whirls upon its axis in a bit under 10 hou Saturn requires 10 hours and 14 minutes. But Saturn mo oblate than Jupiter has an equatorial bulge of 7900 miles is the second largest member of the sun's planetary fam with an equatorial diameter of 75 100 miles.

In addition to her rings, Saturn has nine satellites and *Jupiter* has two larger than Mercury so *has Saturn* o Appropriately enough it is named Titan it is nearly as la as the planet Mars. But most of Saturn's moons are unf tunately not easy to observe with small instruments, and luc would be the observer who could pick up any other th Titan in a 3-inch glass. Were he equipped with a 4-inch te scope however he might be more fortunate Taking extr care to distinguish them from the stars, he should be abl identify Titan Iapetus, Rhea Tethy[illegible] one (named the order of observational possi[illegible] of[illegible]

American Ephemeris for the numerous data necessary to ...dy them.

...So far away from the sun is this planet, and so slowly does ...pace through the heavens that the earth, after completing ...ull revolution around the sun, has but to continue for 13 ...ys before we can see Saturn in the same aspect (for exam... opposition) as in the year before. If Saturn is far distant, ...sider the cases of Uranus, Neptune, and Pluto—the three ...nets discovered since invention of the telescope.

The first one was discovered by William Herschel in 1781 ...re or less by accident. The astronomer was making a ...tematic survey of the stars when he noticed one that re...sed to remain in its place. That was the planet Uranus, which ...about 31,000 miles in diameter and stays on an average of ...1,000,000 miles away from the sun. It can be picked up ...a naked-eye object by people gifted with good eyesight, and ...orehand knowledge of where to look for it. At such a time ...appears as a sixth-magnitude object.

...A 9- to 12-inch telescope, magnifying from 400 to 500 ...meters, is needed before Uranus shows any appreciable ...c, and then it appears as a tiny green object with faint ...tial bands. No permanent markings have been discovered ...the surface, but characteristic cloud bands can always be ...erved with the largest instruments.

The planet has five satellites, all very faint and beyond the ...ch of any but the largest telescopes. And so amateurs, for ...most part, must be content with locating the planet and ...pping its path among the stars.

So, too, must we be with Neptune, though here the task of ...ating the object is more sport. The planet was discovered ...1846 by Adams and Leverrier working independently on ...thematical calculations; and its orbit is just about 1,000,...0,000 miles farther out than Uranus. It can be seen with a ...inch telescope and magnifying power of 15 diameters; ...ough its 30,000 miles of diameter does not become a disc ...til ... use a telescope of 9 to 12 inches aperture.

...At its brightest it is of the eighth magnitude, and the tele...cope shows a faint greenish color. Its two satellites are quite ...t of reach for amateurs, but Neptune offers one consolation ...the telescopist—once located it can easily be followed for ...e rest of the season because it spends nearly 14 years in ...ch section of the zodiac. The positions found in the ephem...is are plotted on a star atlas, and the corresponding object ...the sky that moves daily is the planet and not ... star.

...If Neptune and Uranus have seemed far from the earth, ...en Pluto will make them seem near. For this little world, ...ith ½ the earth ... diameter, is now the outermost planet ...

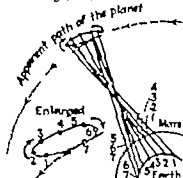


Figure 13 Mars in Retr[...]
When the planets are in positi[...] Mars appears to be moving [...]mally as seen from the earth. Gr[...]ually however the earth pa[...] Mars and the red planet move more slowly As a resul[...] position 2 it apparently start[...] move backward, assuming a re[...]grade motion. It continues [...] position 6, where the relative [...]tions of the two planets hav[...] changed again it once more [...]sumes its normal forward mot[...]

far as known. It takes 248 years for a single trip around [...] sun and twice in each revolution, it crosses the orbit plan[...] Neptune.

Its orbit, most eccentric in the system is farther from [...] circle than that of any of the other major planets. Pluto [...] discovered in 1930 as the result of years of search begun [...] Percival Lowell and finished by workers in the Flagstaff O[...]servatory he had founded for planetary research. At [...] time it was in the constellation of Gemini, but it has [...] moved over into adjacent Cancer where it will be when y[...] read this (unless you are a bit late) for it remains about [...] years within the borders of each star group Needless to s[...] it is completely beyond the range of small telescopes [...] even taxes the power of a 15-inch refractor

The giant planets (Jupiter Saturn Uranus Neptune) [...] similar to each other but differ widely from the earth Ven[...] and Mars. Their atmospheres consist of great layers of [...] noxious gases, ammonia and methane Below this is an i[...]mense thickness of hydrogen underneath which is a thi[...] layer of miles of ice and at the center the dense rocky co[...] The ammonia is in minute crystals and the methane gaseo[...] The cold is inconceivable surface temperatures are ab[...] —200 F on Jupiter to —300 on Neptune Conditions [...] any kind of life on these dark cold distant and forbid[...] worlds would appear impossible.

There is a naked-eye observation which, if made ac[...]dentally and without beforehand knowledge of what is ha[...]pening, is likely to send any amateur scurrying to the libra[...] for an explanation It may be made for any one of [...] planets including Mercury and Venus which are visible wh[...] they present this phenomenon, and it consists quite sim[...]

an apparent reversal of direction by the object under ob-
rvation. Hence it is called retrograde motion.

A planet, Mars for instance, will be seen moving in its customed path west to east among the stars, then gradually wing down, and finally moving east to west, nearly back the direction from which it had been coming. After a short hile, it will resume its old motion again. The explanation, hich is clarified in the diagram on page 62, (fig. 13) lies the relative motions of the planet under observation and e earth. The earth has a greater orbital speed than the outer nets, and as it overtakes and passes one of them, that her planet seems at first to move more slowly then actually be moving backward. A similar effect results when passen-rs in one automobile pass another on the road going in the me direction. As the earth swings farther along, in its orbit, e other planet seems to resume its former motion. In the y Mars and Jupiter apparently describe a retrograde "loop" ile for Saturn, Uranus, Neptune, and Pluto, the loop is most flat, and they seem to "backtrack" along their own ths.

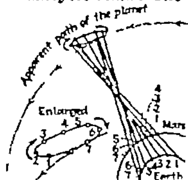


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7 The Moon

THE MOON is one of the most fascinating of celestial bo[dies] and almost invariably the object oftenest viewed by th[e] te[le]scope-user. On account of nearness and size we see the m[oon] with the naked eye and with small optical power can obs[erve] a wealth of detail on the surface. It can be observed scien[tific]ally with various types of telescopes and cameras, and i[t is] often said we know the topography of its surface better th[an] we know some parts of the earth.

The phases of the moon are so obvious a phenomenon th[at] they are noticed by anyone seeing the moon at any time. T[he] cause of phases is easy to understand. The moon is a nea[rly] spherical body and is half-lighted by the sun. As it circles t[he] earth, varying amounts of the lighted half face the ear[th]. Except at full-moon time, only a part of the illumin[ated] spheroid is visible to terrestrials—hence the effect of pha[ses].

At times of new moon, the moon is between us and t[he] sun, and at an eclipse of the sun, exactly so, with the moo[n's] disc silhouetted against the sun. At any other new moon t[han] that producing a solar eclipse, the moon passes by the s[un] either north or south of the latter and the sunlight falls [on] the side of the moon away from the earth; hence the ob[ject] is invisible for this reason as well as being obscured by t[he] blinding glare of the sun. In a day or two after new moon, [we] see a narrow crescent in the west after sunset, for the lun[ar] globe is now *backlighted* by the sun, just as a tennis ball h[eld] away from us and nearly in line with a source of light [is] lighted up from behind and shows the same crescent—but [we] know the rest of the ball is there, even if not illuminated.

During the lunar month the moon travels eastwardly [in] the celestial sphere. Beginning with new moon, it takes po[si]tion successively more and more such that the directions [of] a line from the moon to the earth, and a line from the m[oon] to the sun assume a right angle. This is the first quarter, [one] fourth of the entire spheroid being visible (or half of the disc); it is then in quadrature with the sun, or 90° away from it [in] longitude. Soon more than half of the disc is seen—the "gi[b]bous" phase—until finally at full moon, all th[e] half turn[ed]

ward us is lighted up. Then the longitude of the moon is from the sun, putting the moon directly on the opposite of the earth from the sun; this is also called *opposition*, which time the moon rises at sunset time. After full moon, phases are repeated in reverse order: the disc becomes boos, then at last-quarter phase, and shortly before new on a thin crescent can be seen over the eastern horizon ore sunrise. The "age" of the moon is the time elapsed ce the last new moon. The age of the full moon is about days. "Crescent after new" is obviously to be found east the sun, whether seen faintly in the daylight sky before set, or as a more brilliant object after sundown, whereas crescent before new" is found in the sky west of the sun, t in the eastern sky before sunrise.

The terminator is a word meaning the variable line between illuminated portion at any moment, and the part in dow. Inasmuch as the moon is a spheroid, the terminator ctually a complete circle around the moon, corresponding the circle of illumination on the earth, but the part on opposite side of the moon is always invisible to us. Gener y speaking, if you were at the terminator any time between w and full moon, you would be having sunrise on the moon, ctly if you were on that section (which is seen from the th) between full moon and new you would be experiencing set.

The moon is of some real value to the people of this planet. minating the landscape at night, for instance, it benefits in all latitudes, the effect increasing as we go poleward. In ry high latitudes the moon at certain times illuminates an erwise dark sky during the "long polar night" when the n does not rise at all for weeks. Again, the revolution of moon gives us a basis for the measure of the month. Of atest importance of any of the lunar effects are tides, and moon is mostly responsible for these.

Tides are a phenomenon of regular rise and fall of the sea ters, commonly twice a day. While the earth rotates, the eans pass underneath the moon whose gravitative attraction iodically raises the water level. Shipping would notice the ect at once if the moon were annihilated, for vessels would unable to enter or leave many harbors, so that commercial d passenger trade would suffer untold losses.

Our moon lends itself particularly well to telescopic study account of its nearness to the earth and lack of atmosphere. thing on the moon prevents all the features of its surface m standing out clearly and being sharply defined in our escopes and photographs. To be sure, we are unfor unate in always having but one face of our satellite open to

observation yet that face presents a superb array of t graphic features to delight the eye.

One who has not looked much at the moon with a telesc has no idea of the magnificent views to be encountered. E an experienced observer of lunar landscapes repeatedly fi something new—that is, landscapes under new lights or co tions.

Aside from the purely astronomical sights, there are so phenomena observable when the moon is near the horiz that are caused by refraction effects of the earth's atmosph and the origin of which has nothing to do with the mo Under certain conditions, various refraction effects dis the moon's image into almost unbelievable shapes. The co monest effect is for the otherwise circular disc to become flattened it is almost pumpkin-like Nor does distortion st here occasionally the edges become serrated or saw-like: th even assume a step-like appearance an effect almost ind scribable The bays or indentations "march along the moo disc moving perceptibly even during brief observation, a often end with a part of the disc being separated entir from the rest. Such effects are the result of varying density a thick ocean of air on the earth's surface, with concomita changes in refraction low over the horizon.

Any and all magnifications may be used on the moo Even an opera glass will show the large gray plains, and field-glass, some of the smaller features. But with high-pow binoculars, magnifying 10 to 20 diameters, hundreds of o jects can be identified, although they are still small. T smallest object that we have been able to distinguish wi 18× binoculars is the mountain ringed plain Lalande (1 miles in diameter) which means that hundreds of objects the lunar surface are visible with low magnification.

But to do justice to our satellite, we should use a telescop A 3- or 4-inch refractor opens up a vast field, while reflect of 6 inches aperture and above will reveal marvelous detai Low powers are needed when we wish to include the enti disc for general examination. For more detailed work put higher magnification 60 to 100 diameters are very sat factory for examination of mountain ranges, chains of crat like formations, and topographic details of intermediate siz while powers of 200 to 600 linear diameters are used f close-ups and details of the moon's smaller features, such craters, peaks, and rills.

On the moon, all living organisms needing air for breathi would find it utterly impossible to exist for even a few minut unless they were equipped with special oxygen or air tan As far as we can detect, the moon's atmosphere

nexistent. We can prove by observation the absence of mosphere. There is no ring of light visible around the moon time of a total eclipse of the sun. There are no clouds areas of darkness visible. The satellite's limb stands out as rly as the center of the disc, which would not be so if an osphere existed. Occultations of stars by the moon show instantaneous disappearance or reappearance of the stellar ht in a striking manner which also could not be were atmosphere to absorb the image gradually near the limb. the moon, the sky would always be a night sky except the sun, with the stars—glowing steadily—visible right up its edge. And one could see the larger asteroids, the great ky Way the mysterious zodiacal light, far more brightly n on earth, and even the prominences and corona of the . There would be no ocean of dust, haze, smoke, cloud, t, and fog—no wind, no meteor no aurora, no rainbow ain, or any sound at all—and no twilight and dawn.

Resulting from the absence of air is another phenomenon the enormous temperature range from about 215° F. where sun is near the zenith, to about 240° below zero during lunar night. Likely there are no water bodies on the moon, as we cannot detect sunlight reflected on them. And there uld be no wind or water erosion on the surface. Altogether utterly desolate place, the moon shows no recognizable ns of habitation.

Galileo it was, who first observed the moon in 1610 with telescope, and the satellite has held the attention of telescope-users ever since. Of the early moon students, Hevelius published a chart of the whole surface. This chart was best one for 100 years, and Hevelius was likely responsible many of the names of the surface features. Riccioli published another map in 1651 replacing many of the earlier mes with those of philosophers and scientists of the day. er 200 of Riccioli's names for lunar formations are still ed. Since his time, many others have been added.

The large surface objects of the moon are the gray plains, or ria, the lunar mountain ranges, peaks, ridges, hills; the mountain-walled plains or enclosures (such as Clavius) many them effectually small plains; the mountain-ringed plains like Copernicus) the crater rings craterlets and crater-pits; lets, rills, valleys, and small features, and the bright rays.

The topographic feature largest on earth is the oceans, and next largest the continents. On the moon the large gray known to the ancients as seas correspond perhaps to e oceans, or perhaps to the continents. It is difficult to make good analogy. It is easy to tell why the ancients called them s, for they seem to have been covered with water eons ago

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On the moon, all living organisms needing air for breath would find it utterly impossible to exist for even a few minut unless they were equipped with special oxygen or air ta As far as we can detect, the moon's atmosphere ...

evident. We can prove by observation the absence of [illegible]sphere. There is no ring of light visible around the moon [illegible] time of a total eclipse of the sun. There are no clouds [illegible] areas of haziness visible. The satellite's limb stands out as [sharp]ly as the center of the disc, which would not be so if an [atm]osphere existed. Occultations of stars by the moon show [ins]tantaneous disappearance or reappearance of the stellar [ima]ge in a striking manner which also could not be were [an at]mosphere to absorb the image gradually near the limb. [On] the moon, the sky would always be a night sky except [for] the sun, with the stars—glowing steadily—visible right up [to] its edge. And one could see the larger asteroids, the great [Mil]ky Way the mysterious zodiacal light, far more brightly [tha]n on earth, and even the prominences and corona of the [sun]. There would be no ocean of dust, haze, smoke, cloud, [mis]t, and fog—no wind, no meteor no aurora, no rainbow [...]ain, or any sound at all—and no twilight and dawn.

[Re]sulting from the absence of air is another phenomenon [—]the enormous temperature range (from about 215 F where [the s]un is near the zenith, to about 240° below zero during [the l]unar night. Likely there are no water bodies on the moon, [for] we cannot detect sunlight reflected on them. And there [cou]ld be no wind or water erosion on the surface. Altogether [an u]tterly desolate place, the moon shows no recognizable [tra]ce of habitation.

[G]alileo it was, who first observed the moon in 1610 with [a te]lescope, and the satellite has held the attention of tele-[sco]pe-users ever since. Of the early moon students, Hevelius [...] published a chart of the whole surface. This chart was [th]e best one for 100 years, and Hevelius was likely responsible [for] many of the names of the surface features. Riccioli pub-[lis]hed another map in 1651 replacing many of the earlier [na]mes with those of philosophers and scientists of the day [O]ver 200 of Riccioli's names for lunar formations are still [us]ed. Since his time, many others have been added.

The large surface objects of the moon are the gray plains, or [ma]ria, the lunar mountain ranges, peaks, ridges, hills; the [mo]untain-walled plains or enclosures (such as Clavius) many [of] them effectually small plains; the mountain-ringed plains [(a]s Copernicus) the crater-rings craterlets and crater-pits; [cle]fts, rills, valleys, and small features and the bright rays.

The topographic features largest on earth is the oceans, and [th]e next largest the continents. On the moon the large gray [pla]ins known to the ancients as seas correspond perhaps to [the] oceans, or perhaps to the continents: it is difficult to make [a g]ood analogy. It is easy to tell why the ancients called them [sea]s, for they seem to have been covered with water eons ago

—or it may have been liquid lava (melted rock) Either water or lava appears to have overrun and melted and broken down many mountain ridges and left only rem

In the naming of the maria, the Latin designation of sea used—*mare*—and the name for each denoted some fancied at the time. The original Latin names of the seas, etc., are still professionally used in astronomy even than their English equivalents. Altogether there are about of the gray areas. They include the following large mar

Mare Crisium	Sea of Crises
[illegible]	Sea [illegible]
Mare Imbrium	Sea [illegible]
[illegible]	Sea of V[illegible]
[illegible]	[illegible]

Largest of the above is the Oceanus Procellarum occupy the eastern regions of the moon. Besides these, there are ot smaller maria like Mare Smythii (Smyth's Sea) Lacus Mo (the Lake of Death) and Lacus Somniorum (the Lak Dreams)

The "seas are quite dissimilar in appearance as to siz and extent. Small instruments indicate a level surface most, but as the power is increased more and more irregul ties become apparent in the form of depressions, ridges, l lows, rills. The maria are darker than the rest of the mo commonly the colors are different shades of gray and in the naked-eye view of the "man in the moon" is formed these darker areas appearing against the lighter surface.

Whether or not the maria were ever seas—now at le they are and for millions of years have been what we plains. Probably much of their surface is arid desolate, forbidding surely it is subject to greater extremes of he than we ever know on earth. On account of their indefin outlines in places, it is difficult to estimate the proportion the total lunar surface occupied but the best opinion is more than half the surface is covered by them

Mare Imbrium, a great elliptical plain 750 miles long, bounded on three sides by mountain ranges (the Carpathi the lunar Apennines, the Alps) but the eastern side op into the Oceanus Procellarum Many other formations great disparity of size are to be found in and around region. Everywhere the surface exists at about the same le although there are many low evidence

the surface. A particularly bright as well as rugged area is found just south of the mountain-walled plain Archimedes. The middle of the Alps is a remarkable feature of unknown ..., the Alpine Valley. It is a unique thing, a narrow row about 5 miles wide and 75 miles long, with various ... visible in a glass of good size. There is even a Mount ... near-by.

The Straight Range is interesting, a series of ... or more ... in one straight row about 45 miles long. This range can ... be seen in high-power binoculars, together with the ... Mountains, immediately west. Along the northeast shore of Mare Imbrium is a beautifully curved "bay" known as the Sinus Iridum, which latter bay was probably ... a mare all by itself.

On the north, the bay is bounded by peaks rising 15,000 ... or more above the interior, and containing several crater... and at the ends of this range are ... promontories. ... every conceivable lunar topographic feature can be ... in Mare Imbrium, the crater formations existing in ... all possible forms and sizes. Bright "rays" from Coper... extend for miles over the plain.

The two hemispheres of the moon, northern and southern, ... rather unlike (at least in the halves visible to us) as to ... characters, the southern parts (the top in lunar ... and photos) showing an array of hundreds of separate, ... crater formations, whereas the northern regions have ... mountain ranges. The latter include the mountains ... surrounding Mare Imbrium, and the Haemus Moun... separating Mare Serenitatis from Mare Vaporum. Like ..., there are other ranges scattered over the moon, such as ... Altai Mountains, the Riphaeus Mountains, and some ... at the moon's limb like the Leibnitz Mountains. The ... mountains present an irregular rim to the moon, es... noticed during a total eclipse of the sun, and giving ... to the "Baily's beads."

Mountain ranges on the moon have many peaks with an average height of 5000 to 12,000 feet, and a few are considerably higher than that, as Mt. Huygens in the Apennines, 18,000 feet. The range bordering Sinus Iridum is very steep ... high, as can be detected in the telescope under the proper lighting. In the Leibnitz Mountains near the south pole, some ... the peaks are said by the older selenographers to be much higher, ranging 26,000 to 33,000 feet, a figure which now appears to be definitely overestimated. Compare these eleva... with Mt. Everest, the highest peak on earth (29,000 ...), remembering that the moon is only about ... the earth's

diameter so that, comparatively the mountains of the are considerably greater elevations.

The curved *mountain ridges* themselves are noticed in regions of the maria, running miles in all directions, any discernible system They appear to have rounded likely an example of erosion. Singularly enough, there many unexplained mysteries about our satellite. What have been at work there to produce many of the features tinguished even in a field-glass, we do not know The are one of the examples of erosion they seem to be down as compared to their original height and shape Riphaen Mountains are seemingly another example of There are also numerous isolated mountains, as well as that are dome shaped and many of the latter have craters their tops.

It has been the loose custom to call all the round crater objects simply *craters* However they consist of several The largest are the *mountain-walled plains* The diameter *from about 60 to 140 miles.* Only roughly circular or polyg in shape, they are surrounded by mountain walls, which some cases rise little above the level of the surrounding Yet they are impressive and conspicuous, for the insides depressed below the general level outside the ramparts enclosing walls Clavius is the largest of all—being 140 across—but seen in perspective, near the south pole of moon, it may look smaller than Schickard and Gri Ptolemaeus, near the *middle of the moon* is another of class Inside Clavius can be seen a group of smaller rings, each 5 to 30 miles in diameter together with craterlets and elevations

In some ases however as Archimedes in Mare Im the interior is n t depressed below the surrounding plain type of the class has low walls th t are discontinuous present a ruinous or broken-down cond tion of these parts indicating probably they w re in intact but since suffered erosion *from e ther* w l nic met oric, or activity

The *mountain inged pla n* ar th most numerous, are from 10 to 60 m les n diamet r The h ve pract circular ramparts, w th wall omm ly b ad and inner slopes, which are terraced with w de *peculiarly* ravines. The moon s face is liter lly lm st r d with formations, which are, as in the case of the *details* the bright rays, seen best when on the te n nat r

In all the ring-plains, the floors are m d bly depre below the level of the surrounding wall Most of the mo tain-ringed plains, like Theophilus, Copernicus Tycho,

central peaks. The peak is ordinarily a composite rather a single mass, so that the crater floors are rarely smooth. lateral peaks are often found even when the entire "crater" ...ed, as with Herschel. This object, located just north of ...reat enclosure Ptolemaeus, is only about 23 miles in ...eter. When the terminator—either the sunrise or sunset ...is passing by this crater the latter is thrown into great ...lief and can be clearly seen with 18X binoculars. With a ...scope giving much greater magnification, it has "high, ...ike, circular walls, much terraced, and a fine central ...ntain on the summit of which Schmidt shows a craterlet, ...a double crater and a craterlet on the crest of the north ... (Goodacre). Such is a fragment of typical description ...ater formations.

...is plain from observation that not all the craters have ...tral peaks; why some do, and others do not, cannot be ...wered. It is thought that in many cases the absence of ...k has been brought about by erosion, for very often ...ces can still be observed; but in some, like Longomontanus and Clavius, there is definitely no central cone.

Crater-rings are a third type of round formations. They are ...3 to 10 miles across, approximately. They are circular ...walls only slightly elevated over the outside surface ...the inside is well depressed. Thousands of these small ...ers are scattered over the moon's surface with no systematic arrangement. Too small to appear on our moon chart ...14, page 76) they can be detected on photographs. Just ... of these, Lamé, is shown on the map.

Craterlets are of the same nature as the crater-rings only ...ller and are scattered indiscriminately over the surface. ...y are indeed so numerous as to render impossible an ...mate of their number for inasmuch as they are very ...ll they become more and more evident the higher the ...scope power used. Similarly *crater-pits* cover the surface ...large numbers, being shallow depressions with ordinarily ...surrounding rims.

Crater-chains and *chains of walled plains* attract considerable attention, like the group starting with Herschel and ...Ptolemaeus and extending southward. Such are used as arguments both for and against the opposing theories of the ...on's origin. *Ruined ring-plains* are almost surely an effect ...erosion. Fracastorius is an excellent example—a great ...plain in which the seaward rampart —as it were—has ...n leveled to a chain of low hills with wide passes between ...m, on the places where the original wall once existed. ...any others show this effect in parts of the walls, such as ...ktus and Posidonius. Other minor features include *twin*

craters multiple craters hilltop craters The latter ar most nearly like our terrestrial volcanic craters. They are common however and need high magnification. They can found on the tops of the central peaks of Walter a.

When the moon s crust cooled—so runs the idea held some though not all astronomers—it shrank and cracked Whether this is true or not, there are various *rills* or c found on the surface. Some are flat and broad and oth narrow and deep as on the floor of Alphonsus. The one m clearly visible is the large winding valley known as Schro Valley at the north end of Herodotus. Ordinarily it ca high optical magnification to see the rills, and various selen raphers of note have identified hundreds of rills, espec under oblique lighting.

True well-defined lunar *valleys* are not very numero The best examples are the great Alpine Valley and the Rh Valley The Alpine Valley cuts directly into the Alps. Strai and wide, with steep cliffs it is possible that it may have b caused by a huge meteor striking at a very acute angle. T Rheita Valley is about 15 miles wide and extends for 1 miles it can be found northwest of the formation Fabrici It is noticeably curved and the origin is probably very differ from that of the Alpine Valley possibly subsidence of t land is responsible for the Rheita Valley East of Ptolema In the Mare Nubium, is one of the largest valleys on the mo another lies to the west of Herschel still other types of val are found on the ramparts of the mountain walled enclosu as in Gassendi.

Perhaps more mystery surrounds the nature of the bri *rays* than any other single feature of the moon, for althou they are clearly in evidence even in a small glass, their natu and origin are obscure They con ist of brilliant, narro white streaks always emanating from some crater formati At least 100 of them are known Some extend for hundr of miles over the surface before becoming finally lost. Ev dently they are surface formations only and are probab never found on high elevations They seem to proceed wi out regard to changes of level over which they pass. It also clear that the rays manifest no change that can detected.

Some of the largest of the bright ay ystems are to seen *extending from* Tycho Copernicus *Kepler and* Ar tarchus. Rays from Tycho are the largest and finest of a some going as far as the outer boundary of Mare Nectar Crater-floors in the path of Tycho s rays show that the ra cross the crater formations *hence we infer* that the have been formed after the crate the

-a, however they invariably lose in brightness. Some of -ay systems are composed of much shorter rays.
-o one knows the origin of these brilliant streaks. Perhaps -are occasioned by the deposition of crystalline dust on -side t invisible surface cracks.
-ing range of light shadings, from heavy black, detail-adow to a dazzling white, exists on the moon, although -erage reflective power is that of dark rock. Aristarchus brightest spot on the moon, and Mare Humorum the -st sea.
satellite seems generally to be composed of shades of -and gray yet a few observers see other colors. Thus -een has been distinguished on the Maria Humorum, -m, and Serenitatis. It is also said that the Palus Somnii -golden-yellow to light brown hue, that Mare Frigoris -yellow-green and most remarkable of all, a dull reddish -is supposed to have been seen once in a small crater -ally perfect optical equipment is necessary to distinguish -lors correctly—either reflecting telescope or a highly -ected objective—as well as good seeing conditions of the -phere and good eye. Moreover terrestrial atmospheric -ts must not be confused with intrinsic lunar colors, nor -we be confounded with "penumbral" shadow effects on -moon at certain times. Many expert observers never see -pecial colors on the moon.
-o one knows yet how the moon's topographic features -ated. The two leading theories that attempt to account their origin are the volcanic idea (in which all the crater -objects were formerly volcanic centers, and the gray -s volcanic extrusions) and the meteoric hypothesis -rein such formations resulted from the impact of mete- -es that fell to the moon surface eons ago during the -ative stages of the lunar globe).
The commonest opinion held formerly was the volcanic -, but later Proctor argued that meteorites were respon-. At present opinion is probably about evenly divided -ween the two notions. An immense amount of discussion -taken place, with arguments and objections on each side. -ainst the volcanic theory is the objection of the form of -ypical lunar crater, which differs notably from a terrestrial -cano, the craters on the moon being hollow with no conical -ntain mass. Also it is almost inconceivable that volcanism -ld nearly cover the surface of the moon, as it seems to -e done, with 30,000 craters on our side of the surface, with the maria, whose forms are similar to the mountain-plains and so may have the same origin. Again, the

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necessary to vaporize the meteorite is but a small its total energy and the surplus energy after vaporiz meteorite is still over 400 times the energy of dynamite resulting prodigious explosion. There is no time for tion of heat, and little time for melting, but instead, aterials surrounding will be instantaneously pulverized shock, like the "star dust" of Meteor Crater. The lesser y on the moon would have the effect that for a certain ry of meteor a surprisingly larger crater would be d.

is idea of penetration of a meteorite below the surface he explosion and vaporization of the greater part of the is in accord with the views of Moulton, who claims that the reason why more of the supposedly hidden iron es are not found in meteor craters. The great extent of sion does not seem to be appreciated by scientists in ral. The explosion meteor idea also explains best the t lunar maria, here a larger meteor or perhaps a swarm hese bodies, broke the crust. Mare Imbrium, it is believed, ht have been produced by a 4-mile-in-diameter meteor if ng at 40 miles a second.

The dark color of the lunar seas is also best explained by theory. And lastly the vexing question of the bright rays ms to be more logically solved. Explosion by a meteor ing into the solid crust, perhaps in the subsurface liquid erial, first caused a cracked surface and then a wave of mendous pressure in the liquid that forced some of the erial into the cracks to condense around them at the ace.

The moon is our nearest planetary neighbor to remain ays a certain distance from the earth. From observations has been determined that the mean distance of the moon m the earth is 238,857 miles; but the eccentricity of the it, or ratio by which is differs from a perfect circle, causes distance to vary from 222,000 to 253,000 miles. This ans that *the moon is distant about 60 earth-radii*. This scale should be remembered, rather than the usual ketch showing the moon close to the earth. After the size d shape of the orbit are determined, it is not difficult to lculate the velocity of motion. That is about 2300 miles an ur in its orbit, and equal to the muzzle velocity of very gh-power guns. The distance of the moon is such that the erage angular velocity as seen from the earth is about 33' r hour so that the satellite moves over a space just a bit ore than its own diameter every hour.

As the distance of the moon can be found by triangulation

craters are distributed indiscriminately not followi of crustal weakness as on the earth.

Goodacre claims that the presence of a large bright spots on the surface, of the type of the Linné is the best evidence of volcanic origin At the cen small crater from which it *appears* as if the white composing the rays has been ejected. Radiating rid from Tycho also help in this idea

Objections to the meteoric idea include the fol arguments since the earth and moon have probabl traveling together in the solar system since the "beg meteors should have fallen on each body alike, or they should have fallen correspondingly more on the than the moon, because of the larger size of the f Yet only a comparatively few meteoric gashes have found on earth of which Meteor Crater is the largest there seem to have been no traces left in the rocks to in "fossil falls, or those antedating the present geolog Yet the presence of the earth's atmosphere would co most meteors and hence they would not produce c *Gigantic size and number of craters on the moon in* that the meteors would have been larger and more than is held likely

The *explosive meteoric theory* is a rather new form meteoric idea and possibly has more in its favor than a the other ones. According to the calculations of phys meteor moving at great velocity has so much kinetic e that, when suddenly stopped, it explodes with unpara violence. At 40 miles per second according to Gifford, *400 times the energy of dynamite, and many of the me* come in with greater velocities than that. The questi why is there not a continued bombardment now lik ones which seemingly occurred in the past? If the nu of meteors still coming to the earth s atmosphere millions of years is as great as is proved, what mus colossal "harvest have been in the early eras, it is Very probably the larger masses were all gathered up in the life history of the solar system so that only the ones are *now being drawn in—which* appears reasonab we seldom have large ones striking the earth although it is partly because they are consumed in the atmospher

It is held that if a meteor at 40 miles a second strike moon's surface (of lesser density than the earth s, and no atmosphere to resist the flight) and has its motion in $1/10$ second by the resistance of the globe it will pen about 2 miles below the surface In the $1/10$ second its of translation" is transformed into mo r agita

[illegible]	A Leibnitz Mts.	N Sinus Iridum
[illegible]	B Mare Australe	O Prom. Heraclides
[illegible]	C Altai Mts.	P Alps
[illegible]	D Pyrenees Mts.	Q Alpine Valley
[illegible]	E Mare Smythii	R Riphaen Mts.
[illegible]	F Palus Somnii	S Straight Wall
[illegible]	G Mare Humboldtianum	T Palus Putredinis
[illegible]	H Haemus Mts.	U Palus Nebularum
[illegible]	I Caucasus Mts.	V Cordilleras
[illegible]	J Apennines	W Dörfel Mts.
[illegible]	K Carpathian Mts.	X Lacus Mortis
[illegible]	L Straight Range	Y D'Alembert Mts.
[illegible]	M Promontory Laplace	

hods of surveyors, and as the diameter can be measured he telescope, the size of the moon is easily derived. The neter is about 160 miles or over ¼ that of the earth, the face area about 1/14 of the earth's, and the volume 1/49. hough some of the other satellites in the solar system are ger than our moon, none is as large as our moon compared its primary—the planet around which it revolves. The on's density is 0.6 the earth's, or 3⅓ times the density of ter. The gravity at the surface is ⅙ that of the earth, so t a man weighing 175 pounds on the earth would weigh pounds on the moon (if weighed by a spring balance). trary to the usual opinion, he could not jump six times as h actual height, but could lift his center of gravity six es as high. Also an object thrown by one on the moon uld go six times as far—and probably farther, there being wind resistance. Many curious phenomena would be obved in connection with such a small surface gravity.

Of course all the light of our moon is reflected sunlight. re are no incandescent areas where it could be shining by own light. The easiest method of proving this is to look the dark invisible limb of the moon, which is in shadow. hen it is not illuminated by earthshine we see nothing of surface. Besides this, an observation with the spectrograph ows that the light of the moon is similar in spectral characteristics to sunlight, and thus proves its nature.

Astronomers are often asked how our satellite compares ith the sun in brightness. It is not an easy matter to measure he ratio, but the moon is weaker than most of us would ess. The average of the best photometric measurements ow that the full moon gives 1/465,000 of the sun's brilliance. ore sunlight comes to the earth in a few seconds than moonlight for one year. At the quarter phases, the earth receives 1/465,000 as much light from the moon as from

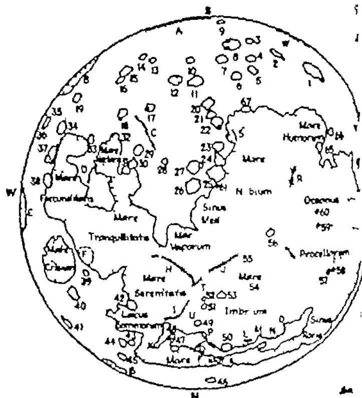


Figure 14 CHAR OF TH MOON

1 Schickard	19 Furnerius	37 Vendeline
2 Schiller	20 W lter	38 Langrenus
3 Scheiner	21 Regi montanus	39 Macrobius
4 Longomontanus	22 Purbach	40 Cleomedes
5 Wilhelm I	23 Arzachel	41 Gauss
6 Tycho	24 Alphonsus	42 Posidonius
7 Maginus	25 Pt lemaeu	43 Hercules
8 Clavius	6 Hipparchus	44 Atlas
9 Newton	27 Albategnu	45 Endymion
10 Cuvier	28 Abulfeda	46 Goldschmid
11 Stöfler	29 Catharina	47 Ari totele
12 Maurolycus	30 Cyrillus	48 Eudoxus
13 Pitiscus	31 Theoph l	49 C unl
14 Vlaco	32 Fracast ro	50 Plat
15 Janssen	33 Sa tbech	51 Aristillus
16 Fabricius	34 Petavius	52 A tolycus
17 Zagut	35 Phillips	53 Archi
18 Piccolomini	36 W Humboldt	54 T

combined effect of the two motions is this: the retardation causes the moon to rise, on the average, about 50 minutes later every night; and this retardation itself fluctuates with the degree of declination of the moon.

When the moon is near the vernal equinox, the increasing declination day by day tends to lessen the normal retardation of the rising time (for the northern hemisphere) but the retardation at setting is increased. In the southern hemisphere the effects are the opposite. Similarly when the moon is near the autumnal equinox, the moonrise is later and later each day by a large amount, but moonset is later each day by the minimum difference—*in the northern hemisphere* and the opposite in the other hemisphere.

These phenomena of changing retardation of rising and setting moon occur each month and are most noticeable in the autumn with the full moon at the vernal equinox. Moonrise takes place nearly simultaneously with sunset. The moon's apparent path is now more nearly parallel to the horizon than at other times, so that at the same hour each evening, it can be successively farther eastward in its longitude, and will be comparatively near the horizon for several days in succession. This is the *harvest moon* and gives us glorious twilight evenings—the nearest full moon to the time when the sun is at the autumnal equinox of September. The next full moon is nearly the same, and goes by the appellation of hunter's moon. In high latitudes the effect of the harvest and hunter's moons is most pronounced.

In case the moon's ascending node corresponds with the autumnal equinox, the moon's path (when the node is rising at the eastern horizon) lies more nearly parallel yet with the horizon, and thus extreme conditions prevail. In latitudes south of the earth's equator the harvest-moon conditions occur at the vernal-equinox times, or spring in the northern hemisphere, but autumn in the southern latitudes.

Strangely enough, our satellite always presents nearly the same face to the earth, wherever it is in its orbit or whatever its phase. It rotates on its axis in exactly the same period as its sidereal period around the earth, and rotation is in the same direction as the revolution. At first it seems to be difficult to understand that the moon can rotate at all, while always presenting one face to the earth, but if you walk around the room in a circle always facing the center of the room, you will find that you have been facing every direction of the compass during the circuit, and have performed a rotation. The same situation holds with the moon; if the moon did not rotate on its axis, it would have to face always the same direc-

the sun Photographs prove that the moon is *yellower sunlight*—contrary to popular ideas It would take five entirely filled with full moons to equal the sun's light.

It is comparatively easy for anyone to get a good idea the general movements of the moon in the heavens, as the movements appear to us that is, the apparent motion After the diurnal motion the apparent motion easiest to serve is the constant eastward motion against the background of distant stars When the moon is apparently near a planet or bright star its motion can be detected with the unaided eye, sometimes in an hour's time The eastward motion is detected by the noticeable retardation of rising each night for it rises perceptibly later every night (or day)

The eastward motion is evidence that the moon goes entirely around the earth in about a month The *sidereal period* is the time taken to pass from a certain star around the heavens and back to the same star Its average 27ᵈ7ʰ43ᵐ11 5 and is used as the sidereal month The mean daily motion is 13 10′58 Another revolution time of the moon is the *synodic period* or the time taken in moving from a certain position with respect to the sun around to the same relative position again as between two successive full moons This interval the synodic month is 29ᵈ 12ʰ 44ᵐ 2ˢ 8 it is the one most closely corresponding to our calendar month.

Of course the times of rising and setting of the moon are of importance to everyone interested in this heavenly body Phenomena of rising and setting are complicated because the fast eastward drift among the constellations and the variation in declination of the moon from day to day (caused by the inclination of the moon's orbit to the equator)

The moon in a month is now north of the equator and now south—ranging among the constellations at the rate of about one constellation in 2½ days The first fact gives the change in declination It will in the northern hemisphere as the north declination increases the moon is nearer the north celestial pole The path of the moon above the horizon becomes longer Hence the greater declination makes for an earlier rising and later setting for the observer of the corresponding hemisphere and vice versa. And if the observer be in the opposite hemisphere the earth from where the moon is south is spoken of as giving corresponding less moonlight per day

Although the daily motion of the moon like that of all other objects is westward, the moon is slowly moving in the other direction (eastward) so that it takes more than a full day between two successive moonrises, or two transits across the meridian or two moonsets. This is the

Time of immersion or emersion in good occultation work an be known accurately within 1 second. Radio time gnals from the Naval Observatory station, an electric clock, perience, and ingenuity are essentials. A list of predicted positions for one's own latitude and longitude can be und in the *American Ephemeris* and some other profes- onal periodicals, notably the *Nautical Almanac* (London) o get the exact predicted time for a particular locality a all amount of computation has to be made with the given ta, to fit the observer's station. Occultation work is more teresting than one would think, and observers become ghly enthusiastic over it.

Eclipses of the moon are never missed by the enthusiastic tronomer. Sufficient data are always given in the profes- onal ephemerides. Commonly each eclipse presents features from the average. As the moon enters the earth's adow the stages are timed, and found to run close to pre diction. The spectacle is often more beautiful and interesting an one would think. The color of the moon at different ages of the eclipse varies typically there is a real copper olor cast over the moon at and near total. During mid- clipse the surface may be more or less visible, from sunlight fracted and reflected from the atmosphere around the disc f the earth. Yet in some lunar eclipses the moon at mid- tality is so dark as to be invisible.

The curved shadow of the earth on our satellite constitutes partial proof of the general spherical form of our planet. One such eclipse is no proof because any object of circular cross-section might cast such a shadow. But if under every circumstance covering many eclipses, the shadow be observed as circular the evidence is highly conclusive for sphericity of our globe.

When an eclipse of the moon begins we have first the event moon enters penumbra, which always occurs near the eastern limb of the moon, whereas solar eclipses begin at the western limb of the sun. This penumbral, or outer region of faint partial shadow can scarcely be detected near the beginning of eclipse but as the eclipse progresses, it gradually becomes evident that the penumbral region is darkening as it nears the central section of the earth's shadow—the umbra.

The umbra is the full shadow and is quite dark. The un- aided eye from the earth sees the umbra with sharp clear edges, but with low-power glasses the shadow appears some what diffuse, and high magnification prevents us entirely from defining the exact edge of the dark shadow. Duration of totality may be from nothing at all, where the eclipse is partial, or may range up to maximum of 1h40m. As to

tion in space and would then *seem* to us to turn, pre... all of its "sides" to us in the course of a revolution.

Actually though, a considerable portion of the ... surface at the edges is alternately visible and then ... away Because of these libration" effects of the moon does not always show precisely the same face to us but certain oscillations back and forth from a mean. Because *libration in latitude* the observer from the earth sees 6½ *beyond one of the poles*, and then half a lunar month later sees beyond the opposite pole by a similar amount.

Libration in longitude allows us to see around the eas... or western limb alternately about 7 45 *farther* than ... mean, this motion putting into view at times certain pla... like Mare Smythii and Mare Humboldtianum, that lie ... the extreme edge. *At the opposite periods during* the lu... month each region can scarcely if at all be seen. For ... moon s angular motion in orbit is variable because of orbit... *ellipticity while the rate of rotation is uniform. Near perig...* its closest approach to the earth it revolves faster th... average and accomplishes 90 in angular measure, or on... *fourth of a revolution in less than one-fourth* of the time ... its period of revolution

Besides exploration of the moon s surface, certain spe... *telescopic observations of interest* may be made of ot... phenomena *involving the moon* such as occultations a... eclipses. Moving along its prescribed path against the sta... background *the moon frequently glides in front of* a s... or planet, hiding one of them from view Inasmuch as t... moon always moves (nearly) eastward in the sky the ... culted object disappears behind the limb of the east... hemisphere at *immersion*, and reappears on the western he... at emersion. *A telescope is needed even for bright* pla... occulted, for the glare of the moon *prevents* the eye fro... noting the exact moment of disappearance or reappearan... *And it must be remembered that an astronomical (inverting...* telescope reverses the image top and bottom as well as si... *for side, so that a star appearing at the left of the moon* ... *the naked eye will seem to be at the right in the telesco...* field

Occultations give *spectacular proof of the absence of lu...* atmosphere, for the *disappearance of a star is instantaneo...* no gradual diminution of light occurs *It suddenly is invisib...* Similarly at the calculated *time the reappearance takes pla...* in an equally startling manner Good observations made w... proper timing are of value to certain professional astronome... who encourage *the work* and who use the results for *impro...* ing the data of celestial *mechanics*.

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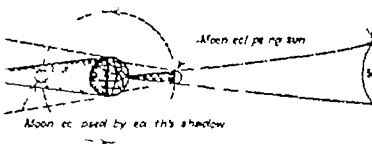


Figure 15

the duration of events, the moon may be in the first part of the penumbra an hour in the deep shadow 1h40m in the last part of the penumbra as long as an hour giving an entire maximum period of about 3 40m for the phenomena.

Moon eclipses can be seen over half of the earth simultaneously although clocks in different time zones read different hours. Not only are the events visible wherever the moon is above the horizon but on account of rotation of the earth actually more than half of the globe is subject to a lunar eclipse The whole half of the earth in moonlight is simply darkened during eclipse The mechanics of solar eclipses are different, and the path of totality is a small strip across one part of the earth

Eclipses of the moon are not nearly as important as those of the sun The main value of lunar eclipses lies in the partial proof of the earth's form the opportunity for study of heat radiation at the moon's surface when eclipsed, and the spectacular effect It touches one's general astronomical interest to note the differences between various eclipses. They may be darker or lighter than the average depending upon the atmosphere around the earth's edge as seen from the moon, and there are apt to be phenomena of lighting effects near the limb which are always unpredictable

8. The Sun

BETWEEN THE sun and the earth are some 93,000,000 miles of nearly empty space, with the temperatures close to the absolute zero of —459°F. But should you carelessly turn even a small telescope on the sun without using a darkened sunglass, it would burn your eye severely.

Which is in the nature both of a warning and of a commentary on the size and heat of this comparatively small star which makes life possible upon the earth. The sun is a huge globe of incandescent gases, measuring 865,380 miles in diameter. It would take a line of 109 earths to reach across its diameter (and more than 1,000,000 to equal its bulk).

But the planets wouldn't remain there long. They would melt into the body of the sun almost instantly, unable to withstand the surface temperature of 11,000°F. The heat at the interior of the star incidentally has been estimated at as much as 40,000,000. Under the conditions of heat and pressure at the sun's core, it is believed, atoms are unable to remain in what is to us their normal state.

These tiny building-blocks of matter are broken down, according to a popular version of one of the current theories. The electrons that revolve about the central nucleus, as the planets do about the sun, are stripped away, and the nuclei are subjected to terrific mutual collisions. It is violent processes of this type, some astronomers believe, that supply the sun with the heat and energy it pours out into space.

As it releases this energy, the sun is at the same time giving away of its own mass and body. Every second over 4,000,000 tons of the star are poured off into the void, and so big is the source of it that scientists estimate it can continue at this rate for several billions of years—even if its resources are not supplemented in some manner from the outside.

The earth receives the tiniest portion of this energy, and yet, as every schoolboy sooner or later discovers, the small amount falling on the surface of a magnifying glass is sufficient to burn wood or start a fire when concentrated at the focus.

The surface of the sun (that which we see when observing it with field-glasses or a telescope) is known as the photo-

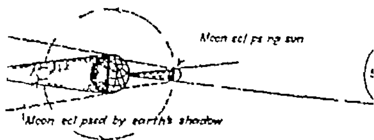


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sphere. It's the first of four outer layers, and directly a it is the reversing layer surrounded by the chromosp which in turn is enveloped by the sun's corona.

Down on the photosphere are the sun-spots. On some d especially during the time of a sun-spot maximum, there sun-spots large enough to be seen with the naked eye. are the big ones, running perhaps from 50 000 to 150, miles in diameter over all into which a handful of e could easily disappear Almost any day during the maxim season as many as 25 smaller ones—still large enough swallow our entire world—are visible in a 2 or 3 inch t scope, or even with a smaller glass.

The spots frequently swim through the sea of meander gases in pairs or clusters, and seem to move across the disc the sun turns on its axis. They prefer solar latitudes betw 5 and 40 both north and south and most live for only few days.

Some, however do stay longer and may even last throug full solar rotation of 25 days and still be going stro Under higher magnification, the spots show a *dark cen* known as the umbra and a lighter surrounding area ca the penumbra. Umbras generally run from a few thousan *50 000 miles in diameter* while the penumbras someti reach 150 000. The entire spot appears black against background of the sun, but if it were not seen against surrounding photosphere it would seem to be white hot, a really is.

Scientists constantly discuss pro and con the possible fects of these sun-spots on daily life here on the earth. A although the precise effects may be debatable, there se *little doubt that the appearance of great numbers of sun-s* in the course of the primary cycle of 11 years does have so influence on the weather auroras, magnetic poles, radio ception, and perhaps even upon the normal course of hum behavior

What then is the nature of these spots which have so m to do with life on the earth? They seem to be *magnetic sto* on the surface of the sun, whirling about a center in a man similar to cyclones on the earth although they are qu different. They are apparently associated with streaks of treme brightness known as *faculae* which are also located the *photosphere and are frequently observed in the vicin* of spots.

These faculae are visible in high-power binoculars, or in 2 inch telescope, especially when observed near the edge the sun, where the photosphere seems to be darker. Th commonly seem *to have longer lives than the assoc*

of sun-spots because of some pull or pressure exerted on them, they may be oblong

These rice grains are separated from each other by 500 miles, a distance that is equal to their diameters, do not retain their form constantly Rather they appear disappear or change their shape continually

The reversing layer is a mass of vapors, entirely of earthly elem nts, that str t hes some 1 00 miles above the photosphere It is cooler th n the surfa and as a result gases in it absorb l ght oming fr m bel w causing dark lines t appear in the solar pe trum During a total eclipse as the moon c ver the surf l rs at the edge the sun the background t brighter pe tral lines s and for an instant these dark lines appea a th s r ally *brilliant in themselves. The pl t second r s s l t the sp*trum of course gives the *reversing* lay r ts n me

Outside of the reversing layer are se er l th t nd miles lighter gases—hydrogen, h lium (first disc t l n the then sought on earth) and perhaps calcium—which compo the chromosphere Here in this third lay r t th m s atmo phere originate the hydrogen prominen es th t rise like clou of luminous smoke thousands and hundr d t th usands m l s Some have been mea ured as limbing 1 000 000 mi above the solar surf ce and they tra el at an az ng speed Here too lie the fl c ul wh h are incand scent masses hydr gen r cal t m probably a sociat d with the pro inences

The natur of th r n a mv t ry It xten ls ll aroun the n and r s t s u that m t h v been imm rsed in without l w ng d wn Th t rm va s w th th un spot cycl when the p t r min n l equ torial t m rs extend several di in t r wh t m mum th t ma is conc tually sph [illegible] pe nt t r l t mper tures 1 800 000 F

For the rona w n ed t t l s l e l p h it these rare for any n j t n th th Th tl re more frequent th n those t h n n h h t ry one be seen at some t n th t the bl ry small area while su r ecl p b f t rth. N w Y rk t n t th w t s t the sun visible on J nu ry 4 1 5 The l d t s n and Manhatt n l l nd th t t nth m l th will be no th r t bl fr m th t t n t O h 144

But som tim we may h n pp rt t to eclipse t the sun w *thout t eling t t* h n and it quite pr bable th t should uch h n we tak d antage t it. For aside from the fact th t it may

9 The Comets

…re excitement has been caused by comets than by any …r objects that appear in the sky. Battles have been stopped …id-career, proclamations have been issued, whole popula…s have been thrown into a panic, kings have abdicated …n their thrones, men have died of fear. Comets were con…ered for centuries as omens of death and destruction. …ple actually … ore charms against them.

…ut all this is no wonder when you consider some of the …ectacular comets that have been seen. There was one in … B.C. that was likened to a flaming torch, in 146 B.C. one …s as bright as the sun. In 530 A.D. a comet reached from …zon to zenith. The second comet to appear in 1811 pos…sed a head nearly 1,000,000 miles in diameter a tail …,000,000 miles in length. The comet of 1744 had six tails … a great fan, and the Great Comet of 1843 had a tail …,000,000 miles in length.

It is not only their spectacular appearance that attracts …ention, but also th…r frequent occurrence. At least 15 …20 comets per cent…y are visible to the casual observer …, on the average, four wondrous ones appear every 100 …rs. In … lifetime one may see several great comets and …dozens others if he makes any effort to find them. …fact, sometimes as many as five come into telescopic view …one year and often one of these is visible to the unaided …e. Many have been as brilliant as Venus and a few bright …ough to be seen in the daytime.

Amateur astronomers find real enjoyment in keeping watch …r comets, occasionally even discovering them and following …em as long as they can be seen. The finding of a comet is a …rtain road to fame, for comets are named after their dis…verers. Find a comet, and you have made your place in …tronomical history. Pons found 27. Messier, Swift, Barnard, …rooks, Perrine, and Giacobini have each found 11 to 20 …mets. In July of 1937 Finsler's Comet attracted wide at…ention. In 1936 amateur astronomer Peltier found his fourth …met, in 1939 his fifth. Although professional astronomers … their telescopes are better equipped for comet discoveries,

visible. As the first speck of the sun returned to view irra tion made it seem larger than it really was. The resul effect was the formation of a diamond ring, with the s of the sun as the diamond and the inner corona as the ri

We would have had less to worry about, and far les see, had we seen the eclipse simply as a partial one. then it would have been a case of watching the moon m across the face of the sun never reaching a point whe covered it completely Just about all the amateur can during a partial eclipse is to time first contact, the ins the moon first nicks the sun s edge, and last contact, w the moon leaves the disc. At intervals he can *percentage of the surface covered measure the drop in* perature, watch the crescents projected by spaces betw leaves and take photographs. The spectacle does not c pare with that of a total eclipse but, as if in partial eclipses may be seen much more frequently

Any solar eclipse in which the center of the moon p over the center of the sun is known as a central eclipse, only when the eclipse is central can it be total. It ca however be central and still *not* be total, for if the m were so far from the earth at the time that it did not ap as big as the sun it would not cover the latter completely the moment of maximum eclipse, there would be a rim sunlight surrounding the moon s disc, and no corona w be visible nor would the darkness of the heavens appro that during a total eclipse. This phenomenon is known as "annular or "ring eclipse, and while it is a striking specta the practical observations for the amateur are substanti the same as those during a partial eclipse.

When the phenomenon is total, of course, he can do t same *things* and more. A *total eclipse has two* more c tacts" than has a partial one—second contact being wl totality begins, third when it ends. The amateur can co and identify the stars that become visible he should note shape, position and number of prominences, the outline a color of the corona, the number of Baily s beads, the wi speed, and direction of the shadow-bands. And always t is the possibility of a comet (otherwise invisible) as the sky is darkened. The loss of light in the sky incid tally can be recorded with so simple an instrument as photographer's photometer

Thus the sun, which is visible every day and theref offers the possibilities of observing its varying seasonal po tion, and which *provides opportunities for daily* telescop observation offers too one of the greatest spectacles that m can ever witness.

the amateurs with more time for comet-sweeping ha surprizing total to their credit.

Of course most comet-discoverers have used telesc yet three railroad workmen in Africa were the first to see report the great Daylight Comet of 1910 Surely ther nothing to equal the great satisfaction of being the first see one of these visitors from outer space, but it is also in esting to keep track of comets once they have been found

Almost every month of the year there is some comet w reach of a telescope. Although the number per year may small, perhaps three some comets can be followed f months or more. The *Handbook of the British Astronom Association* annually lists search ephemerides for all co scheduled to return during the year The Harvard Co Observatory *Announcement Cards* publish the position all comets. *Sky and Telescope* usually has current news observable comets. Some expert on comets writes the mon "Comet Notes" in *Popular Astronomy* Almost every yea comet assumes naked-eye brilliance, and usually before i happens considerable publicity has been given it so that e the newspapers carry directions for finding it.

About every 25 years on the average one of the spectacu comets returns. These cause so much excitement that i hard to escape notice of them. The Great Comet of 18 attracted so much attention that a vintage of wine was nam for it. It was so huge and so threatening that it was rumo among superstitious people that it might have caused Great Lakes of America and the fiords of Norway on a previous visit. Of course these geographic features w caused by other agents.

Most comets do return again and again. Many of them regular members of the solar system and move in defin paths which focus around the sun. Some, with small orb return frequently Encke s Comet, with its nearly circu path, returns every 3½ years. On the other hand, Halley Comet moves in such a large and elongated ellipse that averages about 76 years before coming back near the su When a comet reaches its nearest point to the sun, perihelio it then starts out upon a journey that may carry it far beyo the most distant planet. Some 50 comets are known to ha periods less than 100 years, while the comet of 1811 m take 3000 years to return and Comet 1864 II is estima to require over 2,000 000 years to cover the vast extent its orbit!

Some of the greater comets seem to appear from the dep of space make one circuit of the sun on hairpin curves, th travel away again along almost str ths fo

aps never to return again. Parabolic orbits have been bed to many of these for which but one perihelion visit been recorded in thousands of years. Other famous comets ar to have traveled in toward perihelion on the spreading of a hyperbola, a slightly different form of curve. It has suggested that such comets as these move in a great a curve, only a small part of which passes through the r system, and that they may not belong to the system at Where these comets come from and whence they are nd no one can say. They are not like the short-period ets with the latter's elliptical paths that are obvious mem- of the solar system.

ertainly our understanding is limited by our lack of wledge of these celestial visitors. Were our life span longer even man historic stay upon this planet of a greater od, then we might have other records of the comets which now imagine to have made but one visit to our star. In recent studies have taken many comet paths from the bolic and hyperbolic group (which would indicate that y are not members of the solar system) and added them he elliptical one. No doubt many more of the exceptional et paths will be established as ellipses as the years go on, many comets that we once considered visitors from else- re have proved to be regular members of the system.

And right here is the important reason for the rigorous ntly observation of comets, and the year-by-year check of het paths. For only by the most exhaustive study of each et that comes our way shall we be able to understand the relation of these wandering visitors to the sun and the r family. The amateur can make substantial contributions comet fact and theory by doing his part in this night trol. Day-by-day charts of the comet's position, its chang- place among the stars, sketches and measurements of ad and tail, and photographs are important.

Even though some comets are accredited members of the ar family they have many characteristics that are quite ferent from other members of the group. Their forms are egular and changing, while planets are constant. Comets e partly by their own light and partly by reflected sun- t, hile planets are illuminated only by sunlight. The of most periodic comets are greatly elongated, while planets move in almost perfect circles. Comets may come n any direction and any angle to go round the sun, while major planets all move in nearly the same plane in space go around the sun in the same direction.

of these differences has its effect on the appearance comet as we see it in the sky. Usually when the comet

first appears it is a hazy patch with no well-defined f except the head or coma Coma is the Latin word and comets in both early and late stages correspond the name The coma of a comet is the roundish region. The head region includes not only the coma, and envelopes but also the nucleus if present. The head been observed to be 30 000 to 1 000 000 miles in

As the comet comes within about 250 000,000 the sun, it seems to undergo some excitation. It suffers first of sometimes endless and startling changes. The brightens, and in most comets a brilliant nucleus appears it. Then the coma expands and its material often back away from the sun to form a tail Probably it is the ra tion pressure of the sun that drives the coma material There are comets that nev r go through these changes our observation and never show more than a fuzzy he There are others though that produce jets and strea from the coma and throw off sheath after sheath from head Sometimes the head seems surrounded by lumi envelopes. Coggia s Comet displayed magnificent envelo The light from a comet s nucleus is reflect d sunlight, whe the coma and tail are probably sunlight bsorbed and t re-emitted by gaseous molecules

In certain comets the ch nges have followed in great nu bers and with amazing rapidity Donati s Comet for instan threw off seven envelopes in just a few days Tebbutt s Co of 1861 shed 11 envelopes in weeks Morehouse's Comet 1908 is the comet most fam us for the changes in its co and tail It seem d to requir but a few hours to release la clouds of material

Not all omet ha e nu lei but a great many of them l Sometimes the comet nucl u is less than 100 miles wi but the one in 188 wa 50 000 miles in diameter Th nuclei appear a a ingle br lliant star l ke center in the hea but in the comet of 188 there were six or eight "knots luminous m ter al Very often the nucleus appears to cont and grow brighter just before the appearan e of envelop This change was noted in Donati s Comet some 4 to 7 d before the sheaths appeared and in Morehouse s but a fe hours preceding Here is where the am teur an render greatest service—in keeping record of all changes that m come from hour to hour and day to d y

Normally then a comet first appears w th only the co in view Within this by careful observ tion one may fr quently but not always be able to discover a nucleus Watc ing the nucleus he may find variations in its brightness a its size These may be warnings of *even* greater changes

. A few hours or a few days thereafter nebulosity may ep tenuous envelopes may appear to issue from the and then drift back to form the tail.

e tail is by far the most spectacular of the comet's res. It may be millions of miles in length and extend a larger area than any other celestial body except a r-giant star a star cluster or an entire galaxy Comet 7 II possessed a tail 4,000,000 miles in length, stretch- 105 across the sky Donati's Comet had a tail nearly e that length, and the Great Comet of 1843 possessed a (as mentioned before) of nearly 200,000,000 miles. In 2 the Great Comet of that year had a tail only second to of 1843

The tails of comets are curious phenomena. Often the ghter stars visible to the naked eye have been mentioned visible through comet. On one photographic plate Van sbroeck counted 73 stars of twelfth and thirteenth magni- e isible through the tail of the Pons-Winnecke Comet. mets must be extremely tenuous in nature and, despite ir tremendous size, not massive at all. Probably the heads comets are loose meteoric particles, the outer regions of ich are hurled out by excitation, forced back by radia- n pressure of the sun, and dissipated into microscopic agments to form the tail. Scattered over a tremendous area tiny particles hang perhaps a mile apart, so that a comet's l is almost a vacuum, more tenuous than the air It has en suggested that the carbonized and ultra-rarefied gases t comets contain and the tiny particles that compose the ls are probably illuminated by the shock of electrons from e sun. The tails themselves may actually be hollow cylinders, e envelopes trailing back like a shepherd's horn, and the material is lost to the comet forever

Tails of comets have assumed the greatest variety of form. ome are short and stubby and some, as already suggested, emarkably long The great comet of 1744, De Chéseaux's, ad six tails visible to the naked eye Borelly' of 1903 had e tail barely distinguishable on the photographic plate. ur ill-defined tails followed the comet of 1861 enclosing within them some 3 separate rays. In 1823 a comet had two ils separated by 160

Strangely enough the tails, although they follow the comets n their sunward journey wheel about at perihelion—the closest approach to the sun—so that a line from the sun to the comet runs almost through the tail. Then, however the tail seems to gain on the comet and after perihelion, leads as the comet leaves the sun and starts toward outer regions. There is slight lag, so the tail is seldom exactly on a straight

line from sun to comet head except when far away sun. As the comet approaches the sun the tail is a behind the straight line as the comet leaves, it is still this radius vector—although now it begins to comet head.

Once in a while comets come extremely close to or the sun. In 1680 Newton's Comet went within corona of the sun, 147 000 miles from the surface. a great comet went directly between the earth and in transit. The earth on the other hand went right the tail of Tebbutt's Comet on June 30 1861 the watch for any strange sight, as our planet passed the comet's tail reported a peculiar glow in the faint phosphorescence. And again on May 19 earth passed right through the outer regions of Halley's Comet. Knowing this, a number of made careful observations and measurements night On this occasion they saw nothing, *measured nothing felt nothing to indicate the* comet.

Evidently a comet's tail can do the earth no solid meteoric particles of a comet's head minor earthquake or actually dig a great hole strike the surface of the planet, or a "tidal wave the sea. It is thought that the huge meteor cra was caused by an encounter with a small (of separate fragments) being 400 feet across.

Comet-observing is, in the main, of two comet-seeking a deliberate attempt of the discover new comets. No one knows when a appear in the sky even a great comet. Many h without results nevertheless, many comets covered by patient comet hunting.

For comet-seeking, small areas of the sky *with utmost care noting and checking on ever* nebula, and hazy object. The greatest chance lies near the ecliptic, and in the evening sky also in the morning sky before sunrise. An apert inch with magnification of about a field. Examine the sky object inasmuch as some were first but a "stal Great observers advise th than a large it looks lik take

object's position with that of known objects on the chart. Star atlas, like Norton or Schurig, will include the clusters and nebulae down to about ninth magnitude, and for advanced work Dreyer's New General Catalogue together with its Index Catalogue is really the last word. If your suspected patch of light is not on any of the star fields, the chances are that you have found a comet.

Careful observation for another night and accurate study of its position each time will help to eliminate doubt. First estimate with extreme care and estimate its magnitude by comparison with some neighboring cluster. If the suspected object has shifted its position you need doubt no longer. If there is an observatory near where you live, or some person who is especially interested in comets, you might take one added precaution. The staff at the observatory might know whether the comet is a new one as yet unknown, or an old one returning and already under observation. If the comet should be unknown to them, waste no more time. Send a telegram to Harvard College Observatory describing its location and brightness, and claim credit for the discovery of a comet.

The second type of comet-observing is the picking up of those already discovered. Here the comets can be found without delay if the sky conditions are suitable and if the magnitude of the comet be within the power of the instrument. The principal tool needed besides the telescope is an ephemeris, giving positions of the object at definite times. When the comet's magnitude is 6 or brighter, the positions may be plotted at once on a star chart of visible stars, and the comet then be located with ease. For fainter comets, proceed just as in the case of finding asteroids (as described in the preceding chapter).

Because of the very nature of comets, they seem brighter to the unaided eye than in the finer and larger lens of binoculars and telescopes, for the same amount of light in a comet is spread over a larger area. Sometimes, therefore, naked-eye observations are surprisingly satisfactory and sufficient for attempts to detect the nucleus, head, and outlying tail of most comets. With the telescope, it is usually best to use low powers and wide fields. The greater light-gathering power, the more details observable in the coma, tail, and inner envelopes. Just as one can see more details in a 10-inch than in a 3-inch telescope, so one finds more light at sound images when he uses greater aperture.

There are really many things that one can observe when a comet appears: its position day by day, brightness, shape, size of head, nucleus, appearance of coma, number of envelopes,

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For comet seeking, small areas of the sky are examin with utmost care noting and checking on every star clus nebula, and hazy object The greatest chance of finding lies near the ecliptic, and in the evening sky after sunset, a also in the morning sky before sunrise. An aperture of 4 to inches is preferable with magnification of about 30 diamet and a fairly wide field. Examine the sky minutely stud every suspicious object, inasmuch as some of the faint visual comets discovered were first but a "stain" on the ba ground of the sky Great observers advise that it is better examine a small region closely than a larger area hurriedly.

When a comet first appears it looks like a hazy patch light. At first glance one could take it for a star cluster or nebula. This is the time to get out an atlas and compare t

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changes in the tail number of tails color any features un for that comet and change of velocity as it approaches a then leaves the vicinity of the sun

Often when a comet is first observed its passage is a slow and serene one It takes careful observation to det any change in its location from night to night As the com approaches perihelion its rate of travel increases Just as earth moves most rapidly when nearest to the sun, and moon most swiftly when nearest to the earth, so comets, following the same laws of gravitation, speed up as they c close to the sun

Any comet that is brilliant and spectacular is comm known by the name of its discoverer It always bears an name too to indicate the comet s place in order of disco for the year or the time of its perihelion passage among the comets of that year Thus Donati's Comet in 1858 is called Comet 1858 f for the order of its discovery and Co 1858 VI for the order of its perihelion passage. There also Di Vico's (1846 IV) Coggia s (1874 III) Swift s (1 I) Kopff's (1906 IV) and numerous others.

Occasionally there comes a comet like Morehouse s 1908 which changed so rapidly from night to night that could hardly imagine it the same object. Now and then arrive a comet like the Great Comet of 1882, which visible for 9 months and was known to transit the sun in a while we may see another like the Great Comet of 1 which threw off 11 envelopes from its tail Surely there be others visible in the daytime and about four tim century one brilliant enough to attract observers all over world

There may be another like Biela s which split in two bef the eyes of an observer in 1845 Seven years later the tw *sections returned still farther apart but still traveling* in old orbit. Then when the next approach was eagerly anticip ed, the comet could not be found at all. In its place, howev appeared a shower of meteors. Since that time other mete showers have been associated with the periods and orbit old comets which have disappeared.

There are the cases of Tempel s Comet of 1866 and Leonids of November Tuttle s Comet of 1862 and the Pers of August Biela s Comet and the Andromedes of Novemb It would appear that comets do represent an aggregat meteoric materials which, disintegrating, often give rise to periodic shower of shooting stars.

10 The Meteors

THROUGHOUT interplanetary space there are countless pieces stone and iron most of them whirling about the sun in elliptical paths and some apparently sweeping into the ar system from the depths of interstellar space. On an rage, they are no bigger than a few grains of sand, but e are those that are immense and weigh tons.

More than 100,000,000 of them bombard the earth every , pouring down on the atmosphere in a constant stream. were it not for our surrounding blanket of air they would per the ground in a ceaseless barrage. As it is, these teors, as they are called, are vaporized or burned to a fine by heat resulting from friction with the air and settle perceptibl through the atmosphere to add themselves to vast bulk of the earth. W see them usually for only a ef instant hen the heat has vaporized their surfaces into rown light-emitting envelopes that appear much larger and re brilliant than the original object. Almost immediately er that fleeting glimpse, the average meteor is gone and have seen shooting star"

But see only a few perhaps a half-dozen per hour in ordinary night watching by one person. The rest are er known because they fall over the oceans and deserts other uninhabited areas that take up so much of the rth's surface Or because they come in the daytime, or are lden by clouds, and so escape notice Only the brighter ars are visible to the unaided eye, of course and one obrver in one location will see only a small portion of those hing the earth at any one time—which are additional sons accounting for the comparatively small number seen.

Occasionally one is bright enough to be seen in the day me, and may even explode somewhere in its path. Such an pearance as this, whether it comes during the night or day usually called fire-ball, and in fact any shooting star" at ranges in brightness from that of Jupiter or Venus to mething many times larger and brighter than the full moon classified generally as fire-ball. The term "bolide usually dicates an exploding meteor. The phenomenon is termed

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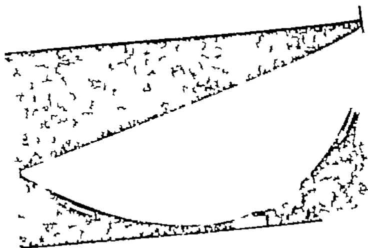
…ed on a star map and traced backward, nearly all seem …anate from the same section of the sky. The shower … its name, usually from the constellation in or near … this radiant point seems to lie, and the swarm of …, which apparently diverged from the constellation of … is known as the Leonid shower.

…is radiation effect, by which the meteors of a shower … to emanate from a point, is only an optical illusion, an …rent radiation that has no connection whatever with the … that lie about it. The meteors appear in the atmosphere …eights that average from 60 to 80 miles, while the stars … trillions of miles away from us. The impression that there … radiant, then, is the effect we obtain when we view these … traveling toward us in parallel paths. Just as when … stand between railroad tracks and look off in the distance … tracks seem to come together, so do these parallel meteor …s, traced backward, seem to come together at a radiant …

…n the case of the Leonids, and they are fairly general, there … annual display of shooting stars every year in Novem…, which occurs as the earth travels through the section of …rbit that intersects the path of the meteor group. But … 33 years the main body of the meteors is at that inter…on and a major shower occurs. The meteors, obviously, … not distributed evenly along their orbit, and even the … swarm may vary in its date of appearance because of …ges induced in its path by the gravitational attraction of … planets. The Leonids, for instance, have failed in their … two "major" appearances to produce anything remotely …ching the fine spectacles of 1833 and 1866, even though … showers of 1931 and 193… produced results far beyond … annual average for "off" years.

…he other meteor showers, similar in nature to the above, … never within recorded history of such events, produced … celestial shows as have the Leonids, but there are a …ber that offer annual spectacles during which the ob…er may see several hundred meteors in the course of a …. Perhaps the richest and most consistent of these is the …eid swarm which appears to visit the earth, during a full …th, from July 15 onward. It reaches its peak about August … to 13, …hen perhaps 50 to 100 meteors an hour may be … after midnight, apparently emanating from the constell… … of Perseus.

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on a star map and traced backward, nearly all seem to emanate from the same section of the sky. The shower gets its name, usually, from the constellation in or near which this "radiant point" seems to lie, and the swarm of meteors which apparently diverged from the constellation of Leo is known as the Leonid shower.

This radiation effect, by which the meteors of a shower appear to emanate from a point, is only an optical illusion, an apparent radiation that has no connection whatever with the stars that lie about it. The meteors appear in the atmosphere at heights that average from 60 to 80 miles, while the stars are trillions of miles away from us. The impression that there is a radiant, then, is the effect we obtain when we view these meteors traveling toward us in parallel paths. Just as, when we stand between railroad tracks and look off in the distance, the tracks seem to come together, so do these parallel meteor paths, traced backward, seem to come together in a radiant point.

In the case of the Leonids, and they are fairly typical, there is an annual display of shooting stars every year in November, which occurs as the earth travels through the portion of the orbit that intersects the path of the meteor group. But every 33 years the main body of the meteors is at the intersection and a major shower occurs. The meteors, obviously, are not distributed evenly along their orbit, and even the main swarm may vary in its date of appearance because of changes induced in its path by the gravitational attraction of major planets. The Leonids, for instance, have failed in their last two major appearances to produce anything remotely resembling the fine spectacles of 1833 and 1866, even though the showers of 1931 and 1932 produced results far beyond the annual average for off years.

The other meteor showers, similar in nature to the above, have never within recorded history of such events, produced such celestial shows as has the Leonids, but there are a number that offer annual spectacles during which the observer may see several hundred meteors in the course of a night. Perhaps the richest and most constant of these is the Perseid swarm, which appears to visit the earth during a full month, from July ... to August ..., reaches its peak about August 10 to 13, when perhaps 50 to 100 meteors an hour may be seen after midnight, apparently emanating from the constellation of Perseus.

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few The latter half of the year from July onward, seem be the best time to look for them, for during that time average number of meteors visible (10 to 15 an hour m midnight) is nearly double the average number per obser per hour of the first 6 months (5 to 8 an hour near m night) And in addition an observer will see twice as m shooting stars from midnight to 6 a.m. as he will from 6 p to midnight.

The latter fact is easily explained, for in the evening are on the rear of the earth as it speeds in its orbit arou the sun. But in the morning, we have been spun around that we are on the front or advancing half of the pla Meteors we see in the evening have to catch up with us, those we see in the morning we meet head on. There are only more of these then but when they are in the atmosph they are traveling much faster than those of the evening And since velocity is an important factor in determining brightness of a meteor those seen in the morning will na ally be brighter than the ones seen earlier in the night

In the atmosphere the speeds of meteors range from 9 t miles per second, and what happens at this speed happen an instant The friction of the air with moving objects wi our normal experience has little effect other than to red speed. But at the velocity of a meteor it is sufficient to r the surface temperature of the object to white heat. T brilliance of the tiny objects is explained by the fact that surface is vaporized forming a luminous gaseous envelope which stands out against th dark sky Since meteors usually small, most of them are burnt out miles above t ground.

Most meteors disappear at an altitude of 40 miles, havi first become visible at from 60 to 80 miles (30 to 100 mil for fire-balls) This is true even if the object has not be burned away for the air retards its speed steadily so that the meteor is large enough to reach the earth it does usually with merely the speed of an object falling freely fro a considerable height. It probably will not be glowing as drops to the ground, and it may even be cool to the touc immediately afterward—because the friction generated he affects only a thin layer of the outer surface which can co rapidly The interior of the stone is deadly cold and there not time for the subsurf to become hot.

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mateurs can be of considerable assistance to the science tronomy in recording their observations of meteors, even ld the records they make be only of an occasional but ual meteor for some other amateur in some other loca- may have seen the same object. By putting the two ts together scientists can tell a good deal about the meteor.

ne of the best and most valuable methods of observation at in which two observers take up positions miles apart watch the same section of the sky. Adequate observations n two such separated points will enable astronomers to pute the height and path of meteors seen by both persons. work, naturally presupposes a good knowledge of the stellations.

The two observers should be stationed not less than 20 es apart, to provide a good base-line for computations. should they be more than 100 miles distant from each er. Dr. Charles P. Olivier, one of the world's foremost horities on meteoric astronomy, recommends a base-line from 40 to 60 miles. The necessary equipment consists of accurate timepiece and a celestial globe or a good set of r charts. A ruler will prove very useful.

What is most desired in such observations is the path of meteor across the heavens, timed as accurately as possible the hour, minute, and, if practicable, the second. The er held at arm's length, will help in trying to fix exactly path of the meteor among the stars after it has vanished. It is of great importance to determine as exactly as possible point at which the meteor was first seen and the point which it disappeared. This can be done, of course, in rela- n to the stars near which it passed, and the terminal points the path indicated in distance (in degrees) from or be- en certain stars or star configurations. It will always prove er to determine the end of the path than the beginning, ce the sudden ppearance of meteor at any particular int is unpredictable.

T make the observations of the greatest possible value, e meteor paths should be marked accurately on star chart, gether ith an arrow indicating direction of flight, and the th should be umbered. With this record should be kept tabulation, giving the number of the meteor on the chart, e points near which it began and ended, its direction, bright s, color, speed (fast, medium, or slow), and comments ncerning any train it might have left in its wake and how ng it lasted, together with remarks about any other unusual haracteristic the meteor may have displayed, such as an xplosion or other sounds. It is more than worth while, too,

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Because a met o s t h bl t n height of 40 miles, it is unl k l th t w ll s ll mile stone crash t the arth hu t d t m w y may think it has done so, but m p b bly t w ll h mph vanished below the horizon—not nt the soil

perhaps, in space. Don't forget to include time, direction [illegible] estimate of brightness, as usual.

[illegible] American Meteor Society, with headquarters at the [illegible] Observatory, Upper Darby, Pa., supplies maps and [illegible] to interested observers, and will in addition offer more [illegible] information upon request. Completed observations [illegible] be sent to the society, where they will be studied care[illegible]. For English observers, the meteor-observing section of [illegible] British Astronomical Association (London) takes meteor [illegible]rts.

[illegible] meteors which actually reach the surface of the earth [illegible] the only celestial objects we can touch and analyze in [illegible]ratories, they are important. They show elements similar [illegible] those of the earth and furnish clues to the conditions of [illegible] space. In other words, they are well worth finding.

[illegible] looking for meteorites is actually another field of ob[illegible]ation—one that requires one's every-day powers of ob[illegible]vation, rather than the watching of the heavens. Frequently [illegible] find unusual pieces of stone which they take to be [illegible]orites and excitedly produce as such. Be cautious and [illegible] the object for certain characteristics before rushing [illegible] laboratory—which is the only place where a final decision [illegible] be made.

The first consideration should be to compare it with the [illegible] of the region. Often the [illegible] meteorite can be [illegible] eliminated on this basis. For [illegible], be[illegible] of their unusual [illegible] [illegible] [illegible] [illegible] don't be fooled by a piece of slag or [illegible] [illegible] [illegible] deceptive because some are predominantly [illegible] while [illegible] are largely stone, and [illegible] third type combines the two [illegible]erials. Because the iron ones are easier to recognize they [illegible] most frequently found. But [illegible] [illegible], exploding with a [illegible] detonation, is apt to scatter dozens of stony fragments [illegible] a small area.

Meteorites usually have [illegible] coating on the [illegible]face which [illegible] from melting as they pass through the atmosphere. [illegible] coating, which is extremely thin, has the appearance of [illegible] crust or varnish, and is sometimes dull or grayish in [illegible]. The surfaces of most meteorites, moreover, show [illegible] or pittings that result from unequal melting of the [illegible]face in that same passage through the air. Those cavities [illegible] the front (as the meteor traveled) are small and deep [illegible] those on the rear are broad and shallow. Eventually [illegible] weathering effects of rain and wind cause the pits to be[illegible] deeper and the crust to disappear with the formation [illegible] iron oxide, or rust.

Often meteorites are found on the surface of the ground,

for the observer to note sky conditions at the time, to with a candid statement as to how accurately he feels he made his observations.

But this is far from the only way in which the amat may make useful records for the professional, even tha it is perhaps the most difficult and exacting method. Obser tions made by one or two persons working together simply charting the paths of the meteors of a particular sho or of an evening are valuable in helping to study radian Not all meteor radiants remain in one fixed position and the stars, and research on the slight shifts occurring in t of a particular shower may reveal extremely interesting fa about meteor distribution.

In working to determine the radiant of a meteor displ the precise direction of the paths of meteors in the sun is needed above everything else A slight error in indicati the beginning and ending points in the meteor paths wil alter the determination of the radiant, but the paths sh be charted accurately and with an arrow-head indicating direction of fall.

The whole process, including a tabulation containing material listed above, can be run through for each met experts find, in about a minute.

If all this seems too much, or beyond your knowledge the constellations (which such work will inevitably imp by the way) then you can still be of help to science. merely counting the number of meteors seen per hour h value in aiding the determination of the density of the met stream Better work might be done perhaps by counting number seen at 5-minute intervals over a considerable pe of time.

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Often meteorites are found on the surface of the ground,

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But this is far from the only way in which the amat may make useful records for the professional, even it is perhaps the most difficult and exacting method. tions made by one or two persons working together simply charting the paths of the meteors of a particular sh or of an evening are valuable in helping to study r Not all meteor radiants remain in one fixed position am the stars, and research on the slight shifts occurring in of a particular shower may reveal extremely interesting about meteor distribution

In working to determine the radiant of a meteor the precise direction of the paths of meteors in the is needed above everything else. A slight error in indi the beginning and ending points in the meteor paths will alter the determination of the radiant, but the paths be charted accurately and with an arrow-head indicating direction of fall.

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Date	Meteor stream	Rad... R.A.
		h m
Jan. 1-4	Quadrantids	15
Jan.	[illegible]	19
Feb.		5 0
Mar		14 32
Apr		18 4
M y [illegible]	[illegible] uarids	22 16
May 11 24	ζ Herculids	16 28
May 30	η Pegasids	22 0
June 2 17	α Scorpiids	16 43
June 27-30	Pons-Winnecke meteors	15 12
[illegible]		20 36
		20 16
		3 12
		22 36
		3 8
Aug. 10-10.	Cygnids	19 20
Aug. 21 23	Draconids	19 24
Aug. 21 31	ζ Draconids	17 28
Sept. 7 15	Perseids	4 4
Sept. 22	α Aurigids	4 36
Oct. 2	Quadrantids	15 20
Oct. 9	Giacobinids	17 40
Oct. 12 23	ε Arietids	2 48
Oct. 18 23	Orionids	6 8
Oct. 31-Nov 6	T urids	3 40
Nov 14-18	Leonids	10 0
Nov 26-Dec. 4	Andromedes*	1 40
Dec. 10-13	Geminids	7 32

Associated with the orbit of Comet 1861 I.
Associated with the orbit of Halley's Comet.
Associated with the orbit of Comet Pons-Winnecke
Associated with the orbit of Comet 1861 V
Begin by July 20.
Associated with the orbit of Comet Giacobini-Zinner 1933 III Great show 1933 and 1946
Continue until Oct. 31
Also called *Bielids* this important meteor stream has been "lost" for years narrow stream having been diverted by planetary perturbations but the meteors may appear again.

or only partly buried because they have lost so much of their velocity in passing through the air But there are, of course, exceptional instances where they have buried themselves deeply in the earth.

Meteor Showers for the Year

We give herewith a table of the principal meteor displays that are known to occur more or less, each year The leading ones, which are quite dependable are indicated with asterisk before the respective dates. The others are sometimes conspicuous but are quite uncertain, so that the observer may

, not see many meteors. According to Prof. C. P. ...wier president of the American Meteor Society the lesser ... (unstarred) meteor streams "probably exist, but there ... hundreds of minor radiants, some doubtless detectable ... year and not perhaps for several more: As a rule, an ...server will not get such a radiant unless he observes all ... —or at least for several hours. Nevertheless, ... meteors in the lesser-known showers have been ob...ed.

Our list of showers is based upon the most important ones ... much longer lists by the famous English observer W. F. ...nning. The data as given for the nine main showers are ...to-date, having been checked by Prof. Olivier (1945) ...sides this, the data of the Meteor Observing Section of the ...tish Astronomical Association are taken into considera...n. The latter society would have us note three of the ...starred showers the Pons-Winnecke meteors, the Taurids, ...d the Andromedes. In looking for the meteors, consider ... late night of the days marked, together with the following ...orning hours.

11 The Asteroids

IN A GREAT broad zone between the orbits of Mars Jupiter and perpetually circling about the sun in giant ell there are thousands of diminutive bodies—each a wor itself These are the asteroids, known also as minor plan.

The asteroids are likely barren worlds, without water heat or living things. Why no water If there had been it would have evaporated into space and there can be atmosphere on these planets, for they are so diminutive their gravity is far too small to hold it The smallest astero visible are less than a mile through, as in the case of Ado Even on Ceres, the largest, a man weighing 175 pounds the earth would weigh only about 6 pounds! On still ones the force of gravity is so weak that he would weigh a fraction of an ounce and naturally would have consider difficulty staying on the ground.

The amount of heat and light received from the sun asteroids is governed by distance from that source at moment, and on the average varies between that received Mars and that by Jupiter The light and heat are not absorbed by clouds as in the case of Venus and Jupiter two cloud covered worlds and although some heat is received, there is no atmosphere to hold it and keep it from radiating away so that the temperature must be near the absolute zero of interplanetary space It scarcely conceivable that the aster oids can be the abode of any life

Asteroids are forever beyond the range of the naked eye with the exception that one of them can just be seen under most favorable condition and at critical times Yet it is not difficult to locate a few of them with low telescopic power—even binoculars—and follow them night after night, during an entire apparition or season of visibility Usually at least *one* can be seen with field glasses and as the size of the glass is increased, a greater and greater number becomes available

The immense zone containing nearly all these minor planets of the solar system is a great ring-shaped belt over 340 000 000 miles from the inner to the o... of ...

ably smaller than Ceres and Pallas apparently this has surface material lighter in tone than the others. Re few astronomers can see Vesta with the naked eye, but it be done during apparitions when the opposition magn is around 6. Juno at times is fainter than magnitude 9 needs high-power binoculars or a 2 inch telescope. the magnitudes are continually varying, on account of relation of the asteroid to the sun and to us.

Astronomically the magnitudes are important first, designate the brightness as seen by us and thus what telescope aperture is needed. Second they are a for determination of size of the minor planet. All but largest are too small for direct measurement in the te So a mean reflecting power of surface is assumed, which or may not be true, but which gives a working basis which to proceed. Then from a knowledge of the orbit and the apparent brightness at opposition, the approximate diam eter is computed.

Actually there is an immense and unknown number of minor planets. The greatest number of known ones occur magnitudes 13 and 14 of which there are about 400 this number decreasing toward the brighter and toward the fainter side There are about 1600 asteroids whose orbit elements are sufficiently well known that positions in righ ascension and declination are computed for each opposition by various institutions assigned by the International Astro nomical Union. These 1600 minor planets might be called the well-known asteroids. Besides these it is estimated the 5000 have been observed at one time or other many of which have been lost or have gone adrift, so to speak, as insufficient observations were secured at the time of appear ance for a good set of data to be made, even by the best computers. Leuschner estimates there must be a total of some 50 000 of these spheroids in existence. The vast majority are probably but a mile (more or less) in diameter

Most of the features of asteroids are of special interest to workers in mathematical astronomy because they concern orbital characteristics. Because we do not know much about the physical nature of the tiny bodies our knowledge is mostly confined to their motions, and to what possible significance they may have in the evolution of the solar system.

The orbits as a whole are much less uniform than those of major planets. The asteroid 944 Hidalgo has a very exceptional orbit. Eccentricity is a numerical relation defining the shape of an ellipse. The nearer it approaches 1 00 the more elongated is the ellipse and the more it departs from a circular form (whose eccentricity is zero) Hi[illegible] orbit

... eccentricity of 0.66, which is a very high value, mak... orbit as elongated as that of a typical comet and more ... with some comets. Its greatest distance from the sun ... it out to a point beyond Saturn's orbit—much beyond ... steroid zone. Yet some asteroids, like 1177 Gonnessia ... se orbit has the eccentricity 0.0068) have orbits more circular than that of Venus, the most circular of the planets.

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The orbits as a whole a m h l m than those of major planets. The st d 944 H d lgo h a ry excep- tional orbit Eccentricity m n m ical d t defining the shape of an ellipse The ne t app oaches 1 00 the more elongated is the ellipse and the more t d p rts from a circular form (whose eccentricity is zero) Hidalgo orbi

catalogs. So you must invariably make a precomputance, a process which is mathematical.

ume now that you are at the telescope and that you a chart before you. If observing, you are commonly the instrument on dates lying between the ones marked the chart, as the probabilities are against your starting at ely the day and hour of the marked positions. Obviously position where the asteroid should be at the moment of fration is somewhere along the apparent path or smooth drawn, the exact place being easily estimated according to the date and hour of observing. After having marked predicted position by interpolating along the path, you ready to observe.

he telescope ideally would be in a really dark place open the constellation containing the asteroid. Hold the chart the telescope (using as dim a light as possible) and tilt that the north-south line on the chart is parallel to the circle of the field of view (this is important) and tilted—that is, with the "south" of the chart toward the celestial pole, not the north point of the horizon. Then a few moments of being in darkness, you can see the configurations just as they are on the chart. (We assume of an inverting telescope.)

locate first the brightest star of the region near the planet- and gradually move the field of view to the planet, identifying all the stars by their configurations and relative positions as on the diagram. The asteroid should be found in proper place, according to the date of observation with to the dates marked on the chart. With practice and dry conditions identifications can often be made in a minutes. At times they have even been made instantly y if one has picked up the asteroid a day or so before is familiar with the star groups, or if the asteroid's place next to a bright star. The planet will, then, be an extra point distinct from all the other points that are real stars moreover by this method you can identify the asteroid confidence without having to wait a few hours for ment of the object to take place against the starry background.

t at the stationary points in their apparent paths, just they are reversing direction, a movement from one to the next is apparent. When the object passes close to a (as seen from the earth) movement can be detected in hour's time, more or less, depending upon circumstances of location and other factors.

be followed by means of the above techniques as the ephemeris and the conditions

sunrise Then with the progress of the season, it can be rising earlier and earlier each day until opposition time, it is at the observer's meridian at midnight. At this t is retrograding. Its appearance continues like that of other outer planet in this way that it rises earlier each ning until finally it is seen in the western sky after s and gradually becomes lost near the next conjunction sun in its astward appar nt motion among the stars takes it inaugurating a new cycle Thi same routine ha to all superior pl net

In observing, on start with an ephemeris of the ast This is a table of exact positions of the object for re intervals of tim and the positions are given in coord of right ascension and declinati n Professional ephem are published annually by the Cincinnati Observatory correspond to th ephemerides of planets as published i *American Eph meris and Nauti al Almanac* of the Naval Observatory the *Nautical Almanac* (London) others These positions are also given for the first four planets in the yearly *Handbook of th Briti h Astrono Association* There are also a very few monthly periodic such as *Popula A tr nomy*—in which the positions are lished f r the a ter id assist to see during the period cov

Half the ntir w rk of pi king up an ast roid (and larly a comet) i s ir pl tting it ccurse fr m the ephe position The simpl st m th d t to pl t the apparent co or else use a ch rt alr dy m de A ch rt an be made w will cov r one t sev r l m nths c urse so that usual further hart w rk i d be d n for th t parti ular appari of th bj ct ext ndi g r n l the ti e t opposition of planet to the n a d n p g m nth

The position d d i l be pl tt d at once on a chart it ther w r p l th qu n s to ea constant h g f t f p t Any tar atlas fixed c rd n t s h se n t d de l n tion framew rk t d n t p t p it n n the a according t th l p t t th d quinox celestial p l t p t Oi h t cannot chang d t n t l th t p bl publish without a n w d t l tl l While change from y r t y n ll t nulative thr ws n bj t t by l n t t t ascen for a number l y r t qu x h i ll tar ch and atlases ha e th t q n x s the l t ns of right ascension nd de l n tion n tw k t ll constell groups pla ed to orrespond w th equ nox tion

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[Most] rainbows are caused by sunlight and are seen in the [day], but occasionally the observer is rewarded by a glimpse [of a] moonbow. So rare are these that sometimes one can[not believe] his eyes.

[The]re are sometimes halos around the sun and moon; they [usually] have a radius of 22° but sometimes 46°. They are com[monl]y soft white circles in the sky caused by reflection of sun[light o]r moonlight from ice crystals high up in the atmosphere. [T]he moon halos are similar to the sun halos which are [regul]arly produced in the daytime sky. There are many varia[tions], however, and although the moon halos seldom have [mu]ch color, the solar phenomena are sometimes vivid circles [of] color with red on the inside and bluish white on the out[side]. When other circles form on the circumference of the [pri]mary circle, a comparatively rare occurrence, they are [kno]wn as mock suns or sun-dogs. The colorless halos are [cau]sed by reflection *from* the surface of ice crystals high in [the] atmosphere, and the colored ones are produced by pris[mat]ic refraction *through* the same crystals.

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[illegible] though they may be [illegible] all for a high degree of accuracy and [illegible] for a well-developed skill. The [illegible] may be [illegible] with the result that the [illegible] as a [illegible] for [illegible]. [illegible] when the [illegible] and [illegible] are [illegible] practice [illegible]. [illegible] by [illegible] but few [illegible] the principles involved in [illegible] the [illegible] can be grasped without undue difficulty and [illegible] understood, the [illegible] for each [illegible] a [illegible] of [illegible] careful [illegible] between [illegible] of the [illegible] to be [illegible] no longer [illegible] of [illegible] "[illegible]" or "[illegible] by [illegible]". [illegible] in degrees clockwise around the horizon from [illegible] point, north being both 0° and 36[illegible] compass, 90 [illegible] it is possible for him to indicate [illegible] when a bearing is given as [illegible] as to how far north of northeast [illegible] around the horizon from the north [illegible] and [illegible] direction, [illegible] of course, that he [illegible] with which to make the measurements.

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[illegible] for example, [illegible] by reference to known landmarks—[illegible] familiar [illegible], the [illegible] a well-mapped country. [illegible] one to the [illegible], and [illegible]

[illegible] of [illegible]
[illegible]
[illegible]
[illegible]

high position for those who knew the secret—was th same stars always passed over the same islands.

Thus, if you studied the heavens well, you need only s toward a star that you knew to be directly above the i that was your destination and you would be guided to it. thermore, you could even judge how near to your desti you were getting, because as you approached it that star w come nearer and nearer to your own zenith. The pri would be the same if you were to see a light atop a tall b ing By walking toward that light, you would approac building and as you approached, the light would se climb higher and higher in the skies.

In actual practice of course it was not quite as simp that. The Polynesian navigator to earn his laurels, had t familiar with *all* the stars which passed over the isla which he sailed, so that as one moved on and ceased to i his destination, he could select another to take its place. since he followed this heavenly guidance without instrum it was only approximate He had to be able to read the si of the seas as well so that he could tell by the birds and fis by clouds, by odors and by countless other small indicatio when he was nearing a landfall.

But the system worked well enough to support a flourish traffic between the islands and win great fame for the mast who guided the ships. Today when an incomparably finer sy tem of navigation exists, so that ships and planes are aim at their geographic targets with pin-point accuracy the navig tor still falls heir to some of the awe with which the ancie beheld him.

And this despite the fact that the actual practice of moder navigation has been stripped of practically all its trigonometri and astronomical mystery and reduced to the point whe with proper instruction and considerable care, almost any in telligent person can find his way by the stars. More than on sailor has learned the tricks of his trade from the books in th New York Public Library—and one Robinson circumnavi gated the globe in a small sailing vessel armed only with th knowledge gained in such a fashion.

Today thanks to the U S. Naval Observatory the Hydro graphic Office and other government agencies, there exist a few brief volumes that, taken together solve all the perplexin riddles of navigation, leaving the sailor little more to do tha make observations and look up the answers in the published tables. The task is much easier than that which confronted the Polynesian master for all the trigonometric and astronomical computations have been worked out in advance and simple arithmetic can take care of the remainder.

[illegible]ption is not, of course, so ridiculously easy that you [illegible] the art by reading one brief chapter in a book de[illegible] numerous other aspects of astronomy nor would any [illegible]udent venture forth on the high seas without giving [illegible] extensive practice in making observations with the [illegible] and performing the other routine tasks involved.
[illegible] operations, simple though they may be in theory and [illegible]ever, call for a high degree of accuracy and, conse[illegible]y for a well-developed skill. The slightest error may be [illegible] magnified, with the result that the navigator might [illegible] destruction as a reward for carelessness. In using the [illegible], an instrument with which the angular distances of [illegible] moon, and stars are determined, practice is essential. You [illegible] discharge a rifle by squeezing the trigger, but few people [illegible] consistently hit the bull's-eye without constant practice. [illegible]ever, the principles involved in following the pathway [illegible] stars can be grasped without undue difficulty and, once [illegible] are understood, the reason for each step in navigation and [illegible] importance of painfully careful observations become clear. [illegible] of the things to be recalled at the start is that the mod[illegible] mariner no longer thinks of directions in such terms as [illegible]th-northeast" or "south by southwest." He measures di[illegible] in degrees clockwise around the horizon from the [illegible] point, north being both 0° and 360°, east being, on the [illegible] compass, 90°, south, 180°, and west, 270°. [illegible] it is possible for him to indicate direction accurately [illegible] simply—when a bearing is given as 35° there is no ques[illegible] as to how far north of northeast it is. He merely marks [illegible] around the horizon from the north point and proceeds in [illegible] direction, assuming, of course, that he possesses a reliable [illegible] with which to make the measurements.
[illegible] are, naturally, other and simpler methods of naviga[illegible] than that which depends upon observations of the stars [illegible] heavenly bodies. But they are inadequate for trans[illegible] [illegible]vel and serve as supplements to celestial navigation [illegible] than as substitutes. Under limited circumstances, they [illegible] stand on their own.
[illegible]Piloting, for example, is nothing more than finding one's [illegible]y by reference to known landmarks—the boatman uses it [illegible] familiar waters, the airplane pilot while flying in short hops [illegible] well-mapped country. Once out of sight of land, however [illegible] is of small use to the mariner, and high in the substratosphere [illegible] aviator too finds it of little aid.
Dead-reckoning is more important, and, when for various [illegible]ons it is impossible to refer to the heavenly bodies, both [illegible] [illegible] back on it for extended periods. Moreover [illegible] [illegible]ent dead-reckoning with radio signals—

high position for those who knew the secret—was that the same stars always passed over the same islands.

Thus, if you studied the heavens well, you need only set sail toward a star that you knew to be directly above the island that was your destination and you would be guided to it. Furthermore you could even judge how near to your destination you were getting, because as you approached it that star would come nearer and nearer to your own zenith. The principle would be the same if you were to see a light atop a tall building. By walking toward that light, you would approach the building and as you approached the light would seem to *climb higher and higher in the skies.*

In actual practice, of course, it was not quite as simple as that. The Polynesian navigator to earn his laurels, had to be familiar with *all* the stars which passed over the islands to which he sailed so that, as one moved on and ceased to mark his destination, he could select another to take its place. And since he followed this heavenly guidance without instruments it was only approximate. He had to be able to read the signs of the seas as well so that he could tell by the birds and fishes, by clouds, by odors, and by countless other small indications when he was nearing a landfall.

But the system worked well enough to support a flourishing traffic between the islands and win great fame for the man who guided the ships. Today when an incomparably finer system of navigation exists, so that ships and planes are aimed at their geographic targets with pin point accuracy the navigator still falls heir to some of the awe with which the ancients beheld him.

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Plate XIII Meteor Crater

...om the south rim of Meteor Crater, near Canyon Diablo, Arizona, ... camera looks nearly ... mile across to the depression in the northern ... part, which ... believed to have resulted from the north-south angle ... descent of the meteor or small comet that caused the earth-scar. The ... floor of the crater ... about 500 feet below the northern rim. In the ... background looms the snow-capped San Francisco peak, highest in ... Photograph by Hubert J. Bernhard



Plate XI. A S[illegible] "Smoke Ring." The well known Ring Nebula [illegible] Lyra [illegible] Messier 5[illegible]. In [illegible] telescope it [illegible] appears just like [illegible] smoke ring. [illegible] a large instrument the complex structural detail [illegible] visible [illegible] as well as the 15th magnitude star in the middle.
(*Mt. W[illegible] Observatory.*)



Plate XII. The Northern Aurora. A [illegible] appearance [illegible] the [illegible] [illegible]ern lights.





Plate XI. A Stellar "Smoke Ring." The well known Ring Nebula in Lyra, Messier 57. In a telescope it appears just like a smoke ring. In a large instrument the complex structural details are visible as well as the 15th magnitude star in the middle.

(Mt. Wilson Observatory)



Plate XII. The Northern Aurora. A remarkable appearance of the aurora borealis, or northern light.







Plate VII HALLEY'S COMET Halley's, one of the largest of the naked eye comets, had a proportionally large nucleus, as shown in this photograph. Last seen in 1910, the comet will not return to the earth again until 1986. *(Photograph by Perrine Observatorio Astronómico Córdoba Argentina.)*



Plate VIII JUPITER The surface of Jupiter, largest planet in the solar system, is belted by clouds which are characterized by intricate and ever-changing details. Actually the atmosphere is composed of deadly gases at extremely low temperatures. *(Mt. Wilson Observatory)*

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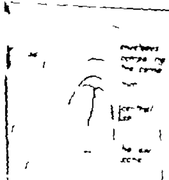




Plate VIII. JUPITER. The su f ce of J pit l rges planet the sol system, is belted by louds which re ha acterized by tra t nd ever-changing details. Actually the tmosphere is composed f de dly gases at extremely low temperat res. *(Mt. Wilson Observatory.)*

ate V. Tebbutt's Comet. The Great Comet of 1861 discovered with the naked eye by John Tebbutt of New South Wales, an amateur comet observer, exhibited star-like nucleus, typical coma and brilliant bifurcated tail. Pastel by Trouvelot. Charles Scribner's.







ate VI. Parts of a Comet are illustrated here by the Great Comet of 1861 shown in diagram and photograph. This comet, discovered by Tebbutt, was an extraordinary object. It threw off 11 envelopes in a day. On June 30 it is supposed the earth passed through the tail; peculiar atmospheric effects were observed. Photograph: Warren de la Rue. From Guillemin, *Le Ciel*.

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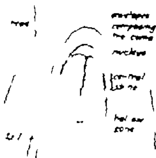




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Plat IV T e Moo C ose Up

Rugged mountains, stretches f barren plains, deep lleys, innumerab crater forms—all the rough hewn features f the luna surfa e shown in this pict re of the south pola region f the moon f Pt lemaeu t the pole (*Mt W R n Observ t y*)

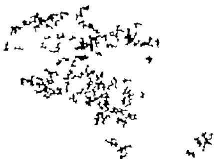


Plate [illegible]

[illegible] close up of Crux, the Southern Cross, showing the [illegible] sack dark nebula to the lower left [illegible] the [illegible] rich region [illegible] When transiting the meridian the two stars forming [illegible] of the cross are nearly perpendicular to the horizon, [illegible] becomes stellar pointers (Union Observatory, Johannesburg [illegible])



Plat IV I Mo (ose Up)

Rugged mountains, stretches f barre plain, deep valleys, inn merable crater forms—all the rough hewn feat es f the lunar surfa are shown in this picture f the south pola region f the moon from Pt lemaeus t the pole (*Mt W il Observatory*)



Plate II Ringed Planet The large planet Saturn as dra b Mentore Maggini at Arcetri Italy th nearly the maximum opening f the rings as seen from the rth Division of the rings is pparent nd lso the subdi ision of the outer ring. Th belted and spotted ppea nc f the planet the darker polar the irregularities f the shadow f the planet on the rings, details in the outer ring are some f the tures observ

Plat III Sun S ot The sola d s t ppeared t the t me of the April, 1930 sun spot maximum The largest spots, which fte occur in groups, were each huge enough t engulf many earth (M t W il on Observatory)